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Harada

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(45) **Date of Patent: May 30, 2023**

(54) **CONTROL SYSTEM FOR WORK VEHICLE, METHOD, AND WORK VEHICLE**

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(72) Inventor: **Junji Harada**, Tokyo (JP)

(73) Assignee: **KOMATSU LTD.**, Tokyo (JP)

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(51) **Int. Cl.**
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E02F 3/76 (2006.01)
E02F 9/22 (2006.01)

(52) **U.S. Cl.**
CPC ***E02F 9/262*** (2013.01); ***E02F 3/7618*** (2013.01); ***E02F 9/2278*** (2013.01)

(58) **Field of Classification Search**
CPC E02F 9/262; E02F 3/7618; E02F 9/2278; E02F 9/2029; E02F 9/2045; E02F 9/2296; E02F 9/265; E02F 3/3677; E02F 3/652
See application file for complete search history.

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Assistant Examiner — Faris Asim Shaikh
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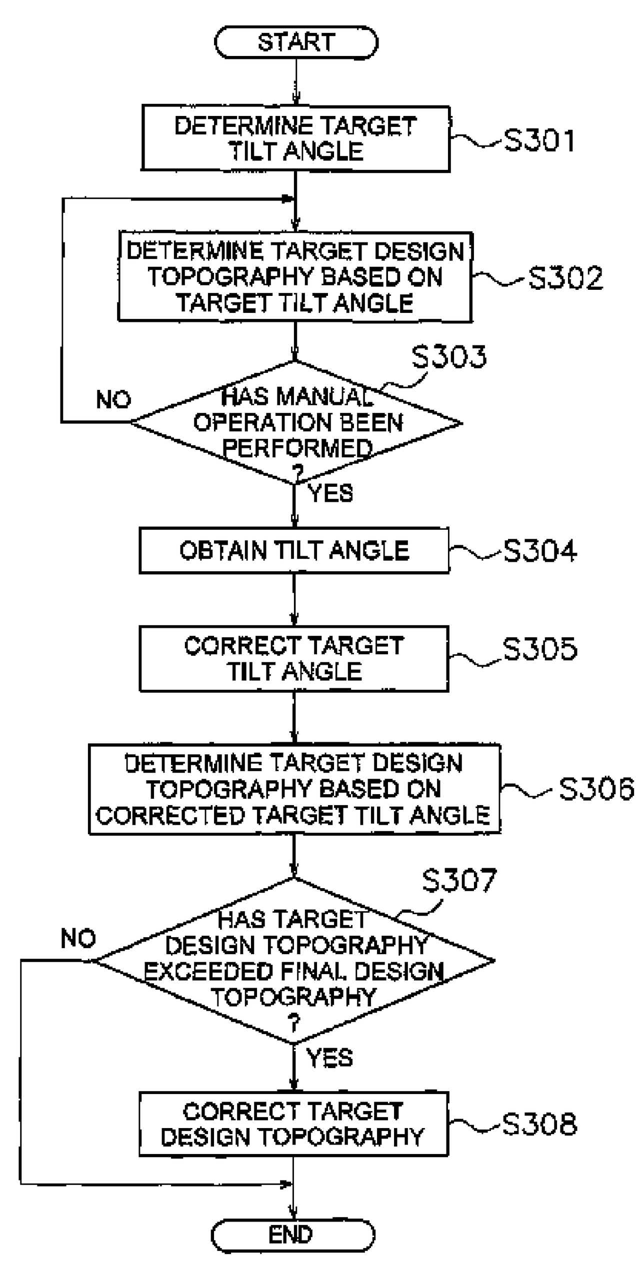
(57) **ABSTRACT**

A work vehicle includes a work implement. A control system for the work vehicle includes an operating device that outputs an operation signal indicative of an operation by an operator, and a controller that communicates with the operating device and controls the work implement. The controller determines a target design topography indicative of a target topography. The controller generates a command signal to operate the work implement in accordance with the target design topography. When a tilt angle of the work implement is changed with an operation of the operating device, the controller corrects the tilt angle of the work implement in accordance with the changed tilt angle.

20 Claims, 28 Drawing Sheets



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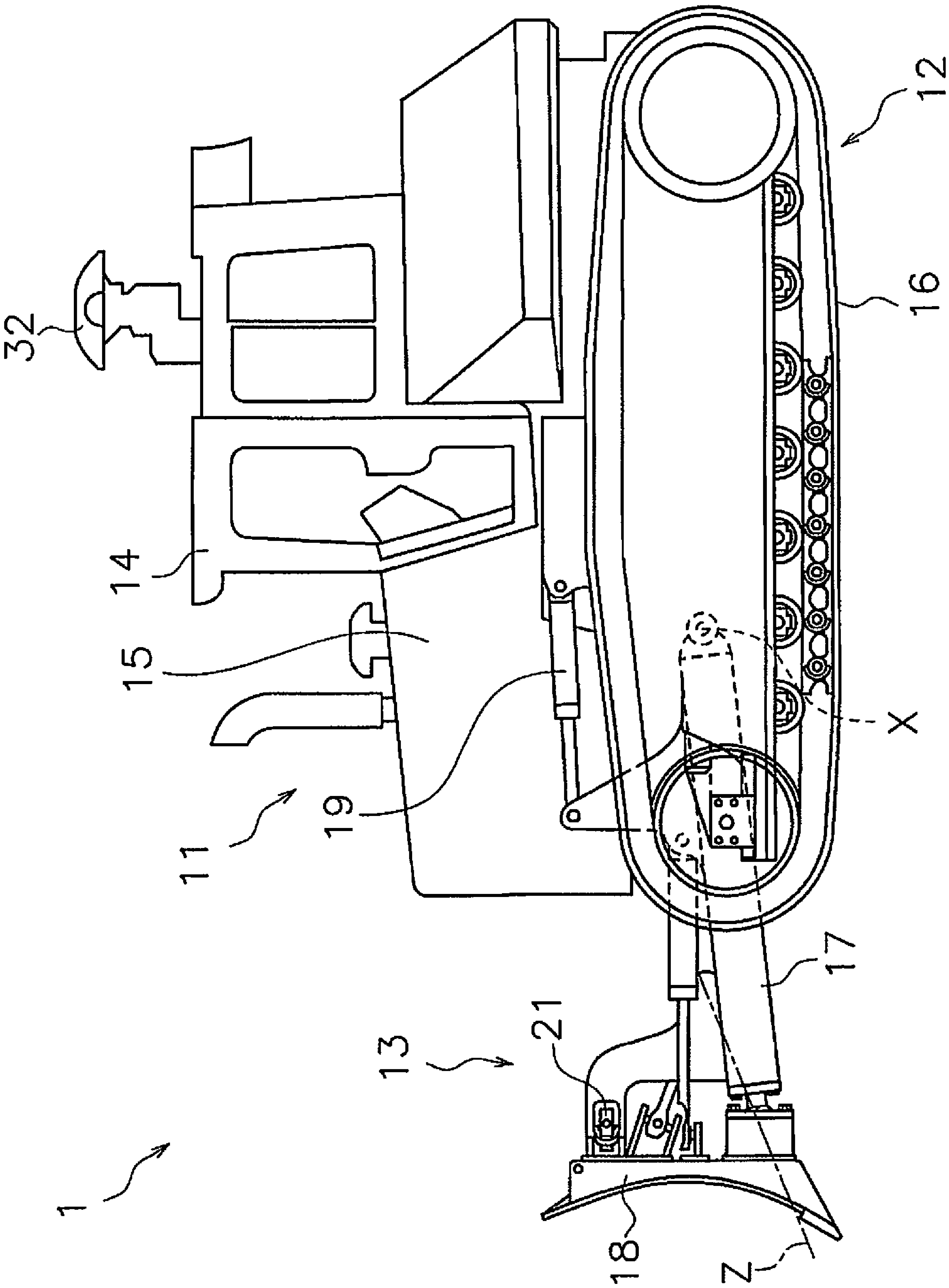
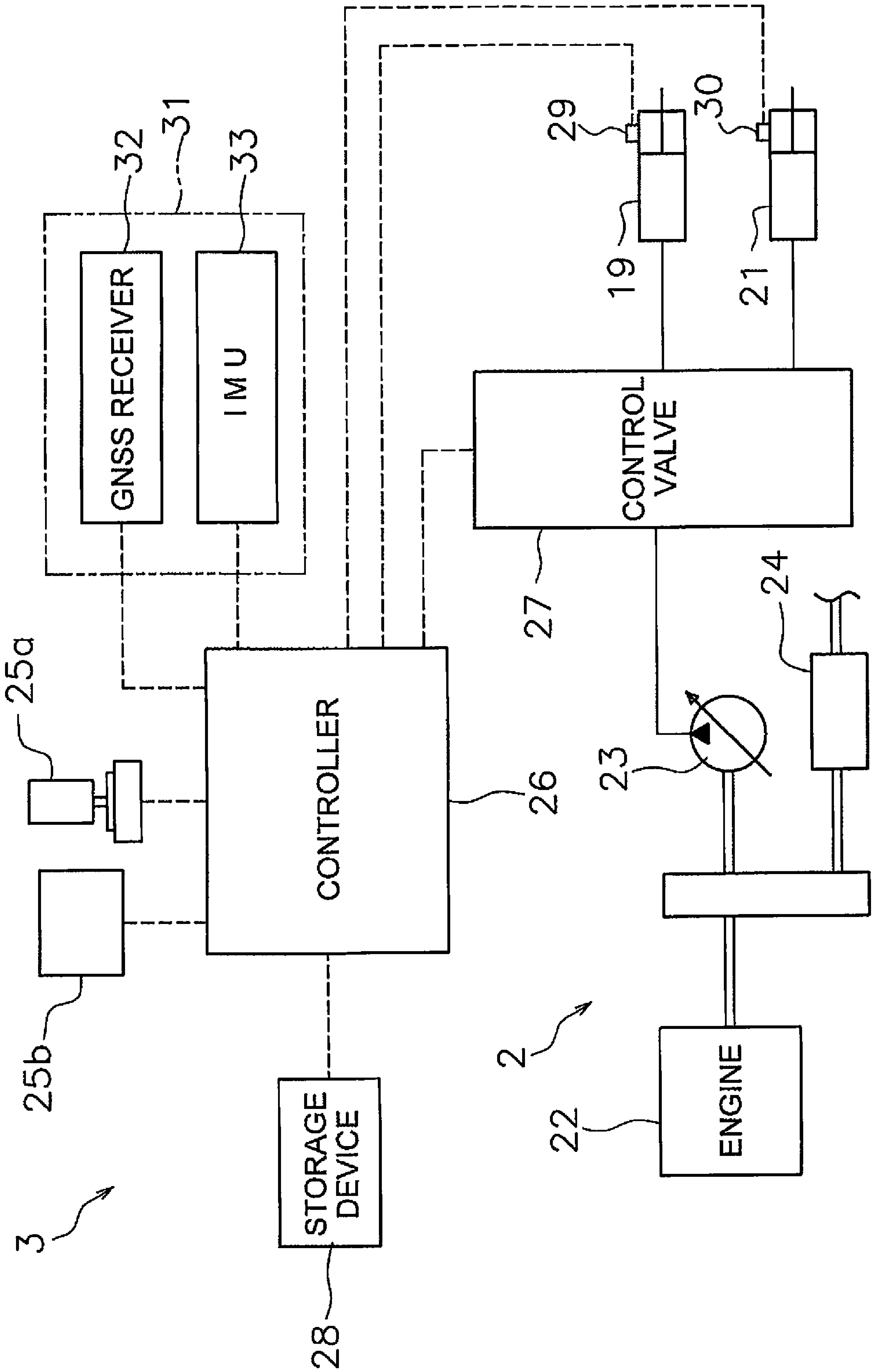


FIG. 1


GNSS RECEIVER
IMU
CONTROLLER
CONTROL VALVE
STORAGE DEVICE
ENGINE
2
3
19
21
22
23
24
25a
25b
26
27
28
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30
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32
33

FIG. 2

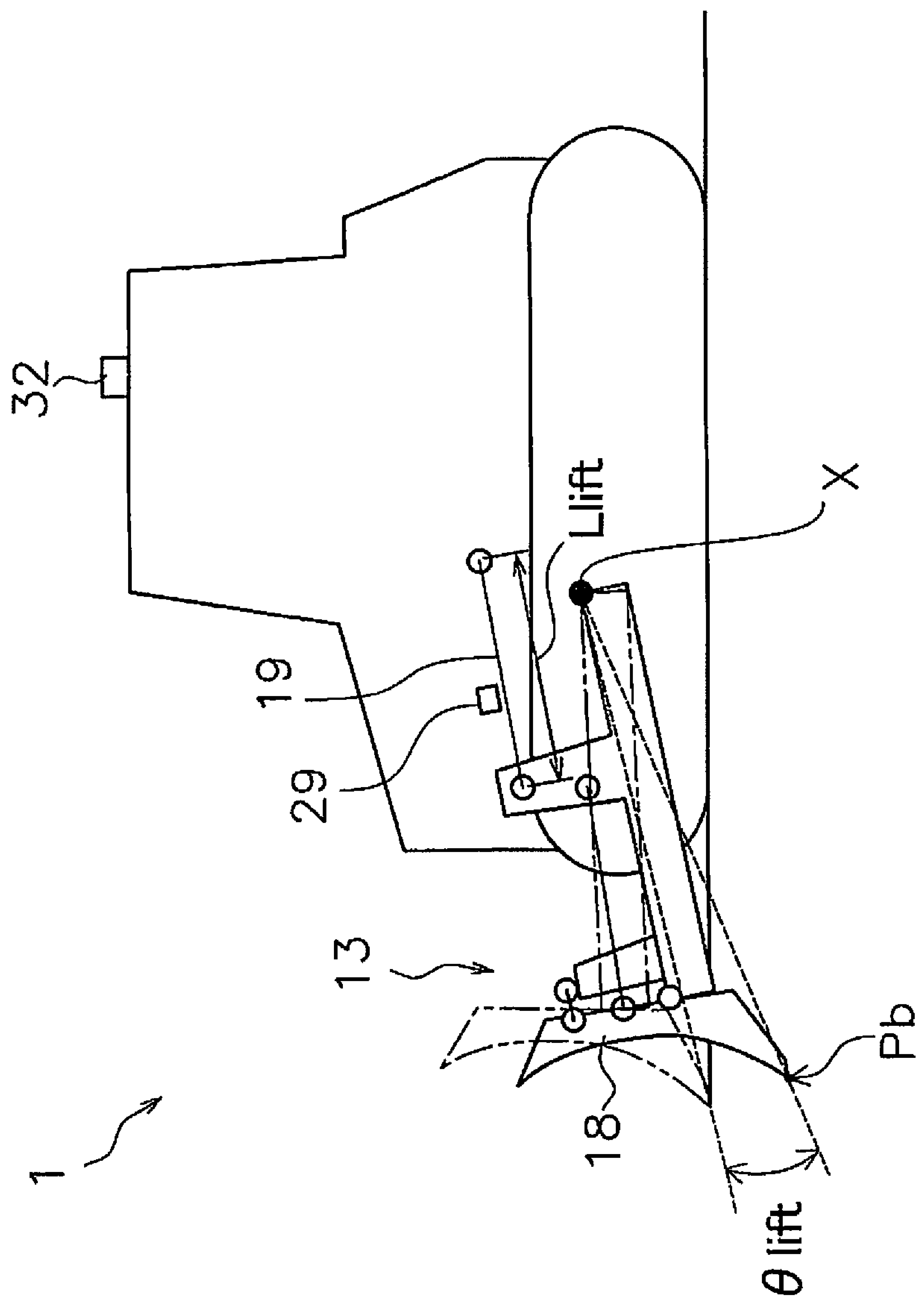

FIG. 3

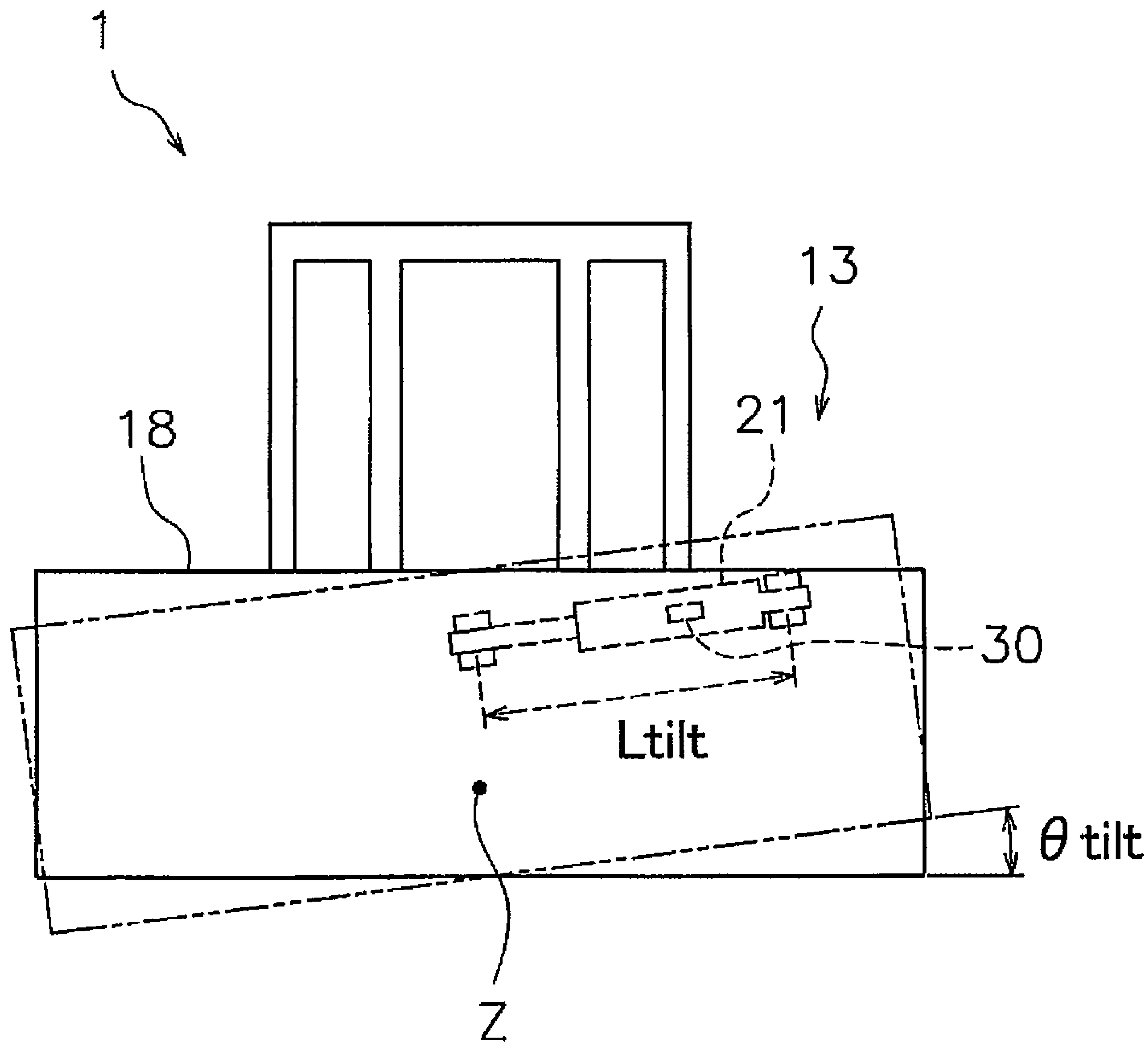

FIG. 4

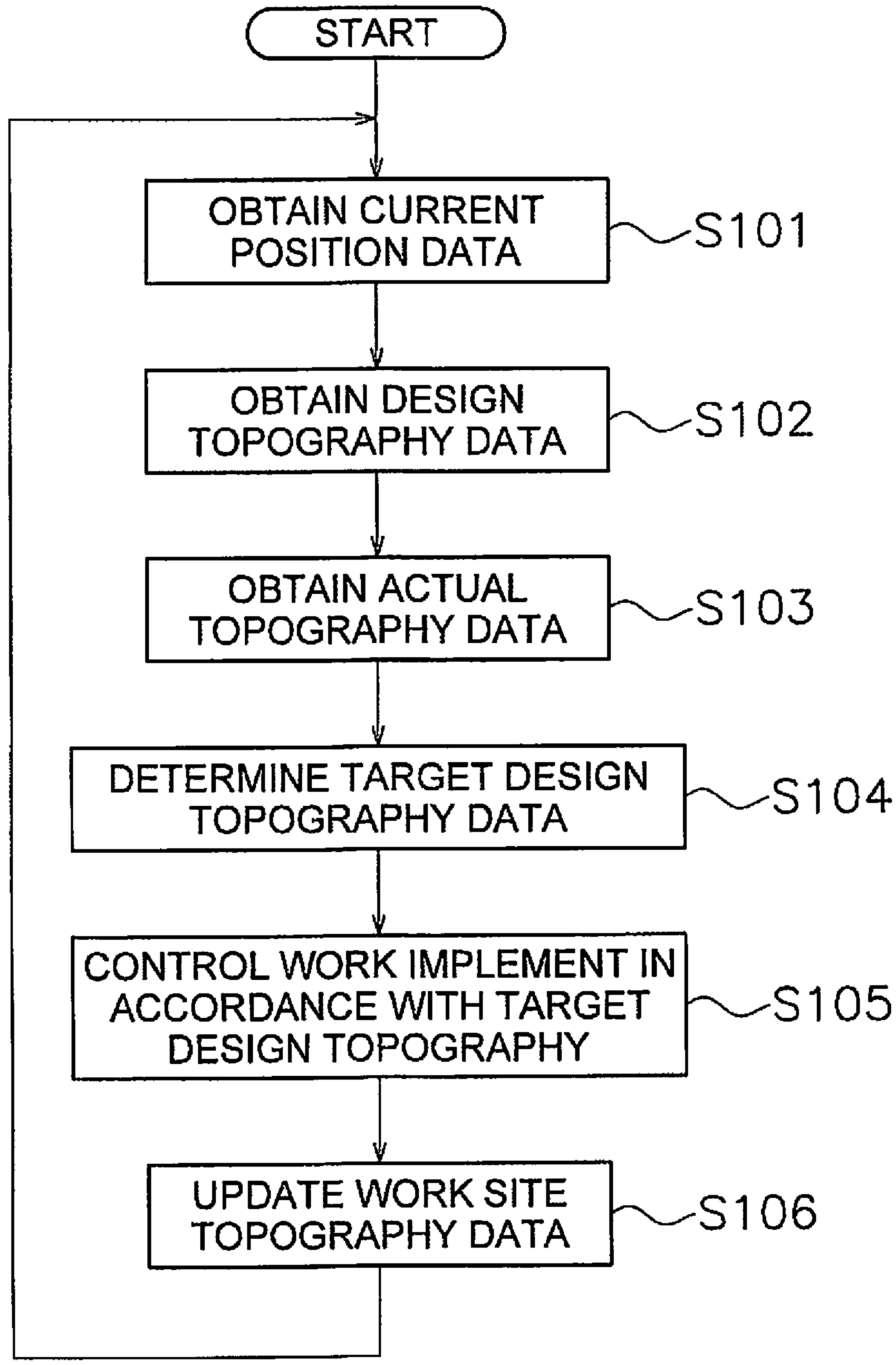
START
OBTAIN CURRENT POSITION DATA
S101
OBTAIN DESIGN TOPOGRAPHY DATA
S102
OBTAIN ACTUAL TOPOGRAPHY DATA
S103
DETERMINE TARGET DESIGN TOPOGRAPHY DATA
S104
CONTROL WORK IMPLEMENT IN ACCORDANCE WITH TARGET DESIGN TOPOGRAPHY
S105
UPDATE WORK SITE TOPOGRAPHY DATA
S106

FIG. 5

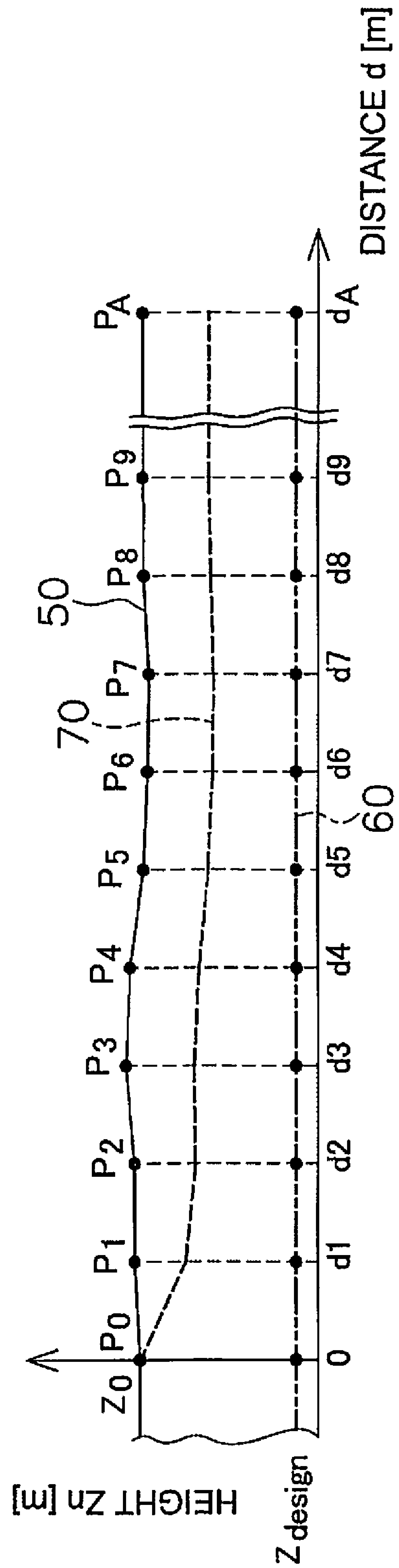
HEIGHT Zn [m]
Zdesign
Z0
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
PA
0
d1
d2
d3
d4
d5
d6
d7
d8
d9
dA
DISTANCE d [m]
50
60
70

FIG. 6

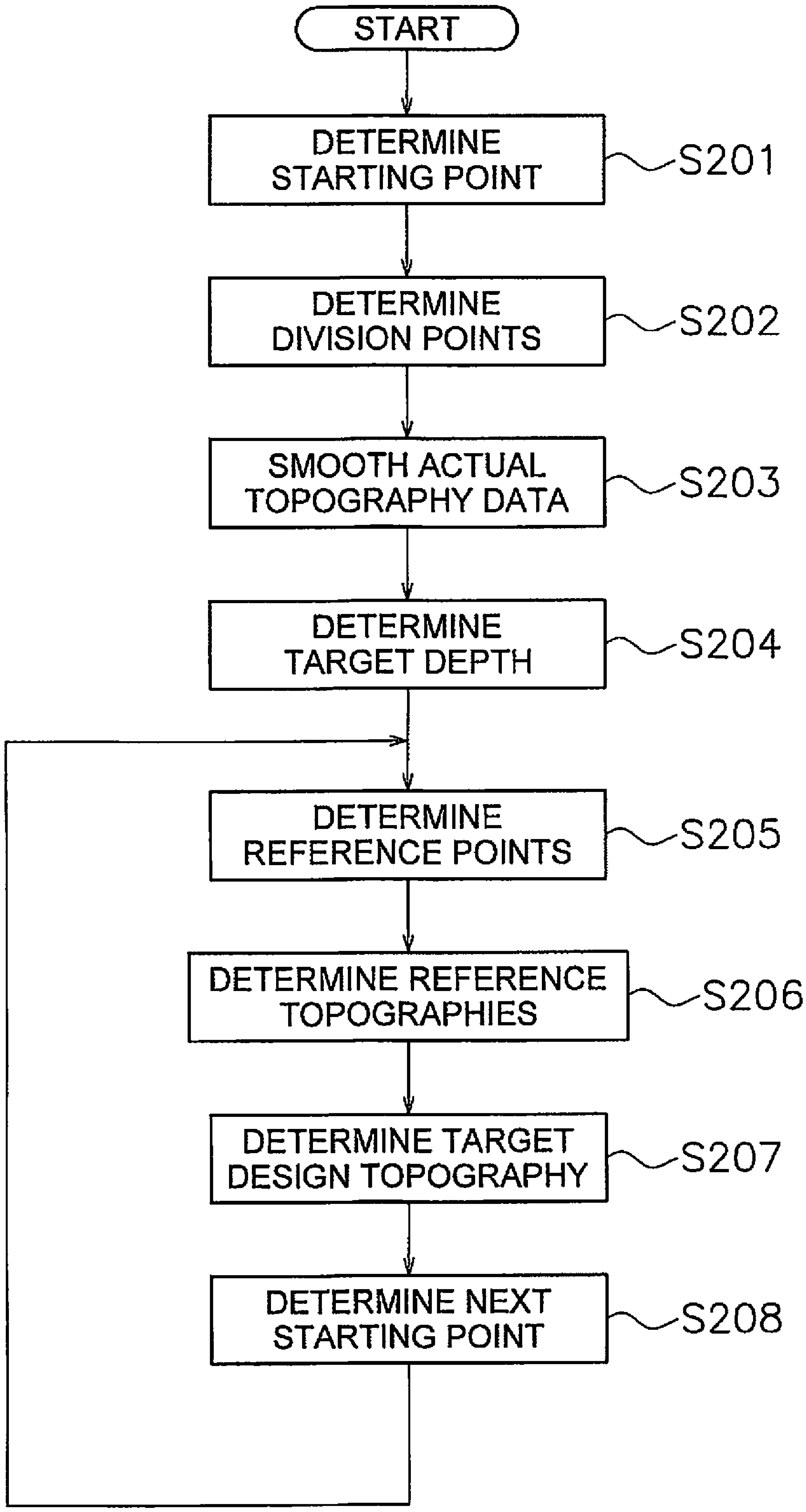
START
DETERMINE STARTING POINT
S201
DETERMINE DIVISION POINTS
S202
SMOOTH ACTUAL TOPOGRAPHY DATA
S203
DETERMINE TARGET DEPTH
S204
DETERMINE REFERENCE POINTS
S205
DETERMINE REFERENCE TOPOGRAPHIES
S206
DETERMINE TARGET DESIGN TOPOGRAPHY
S207
DETERMINE NEXT STARTING POINT
S208

FIG. 7

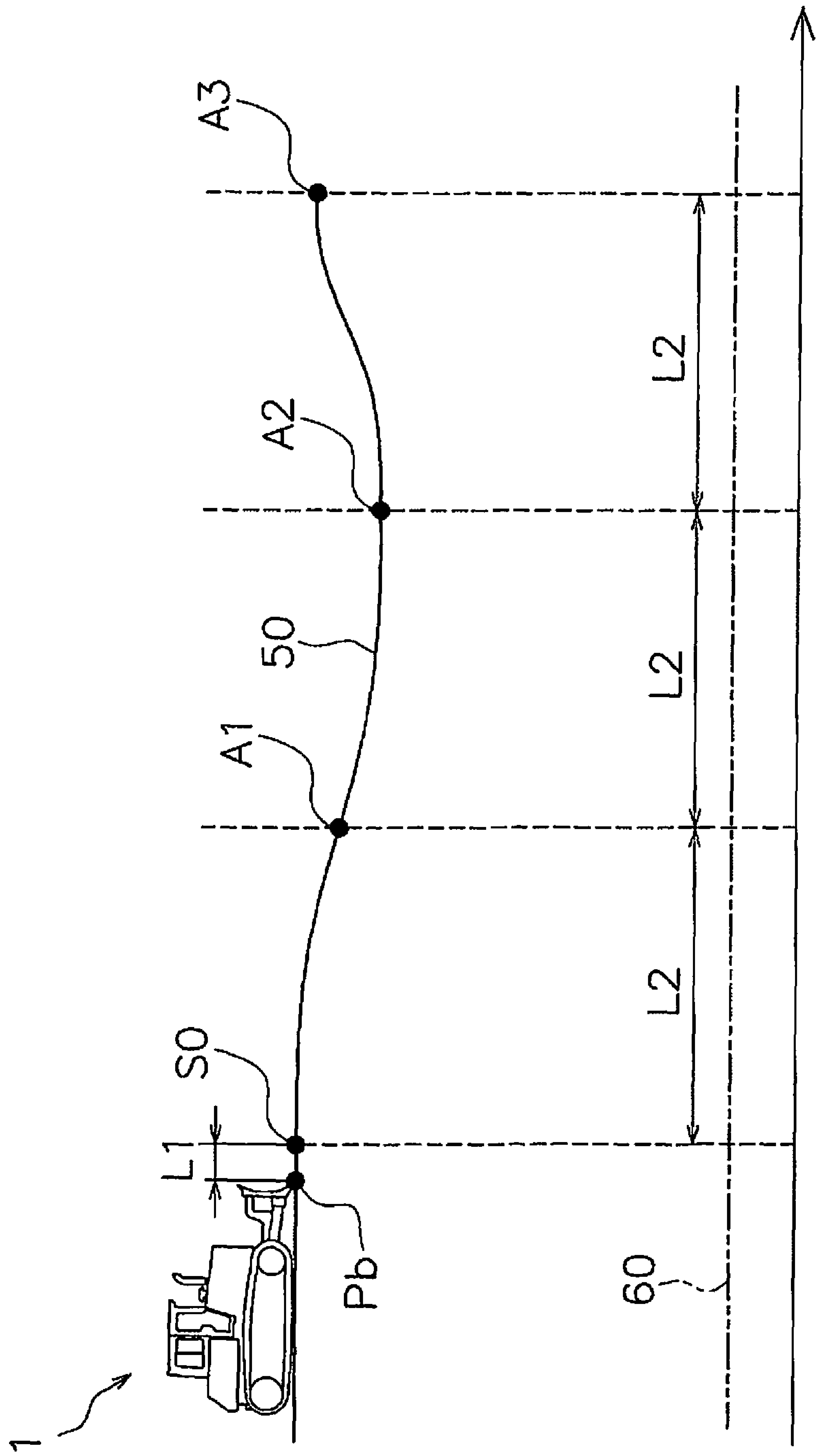

FIG. 8

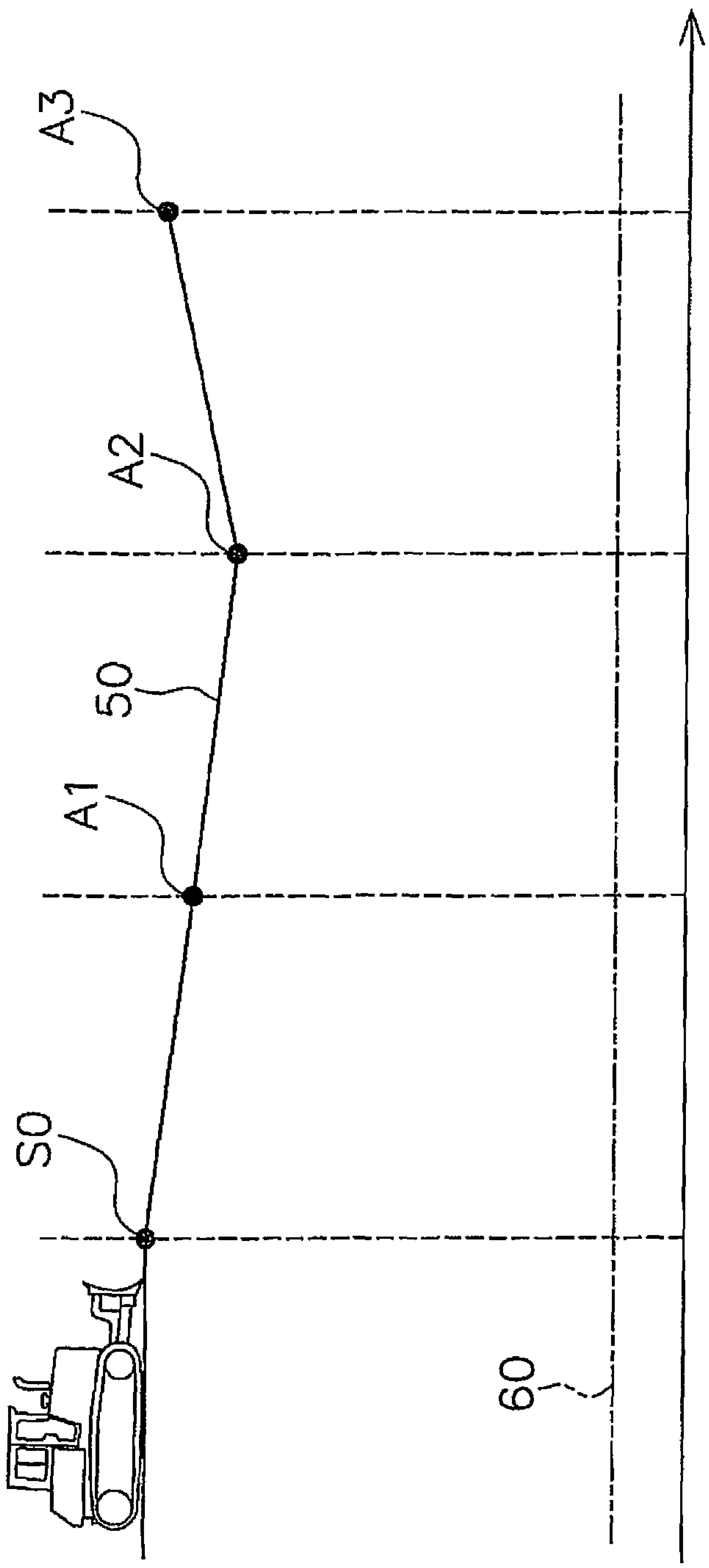

FIG. 9

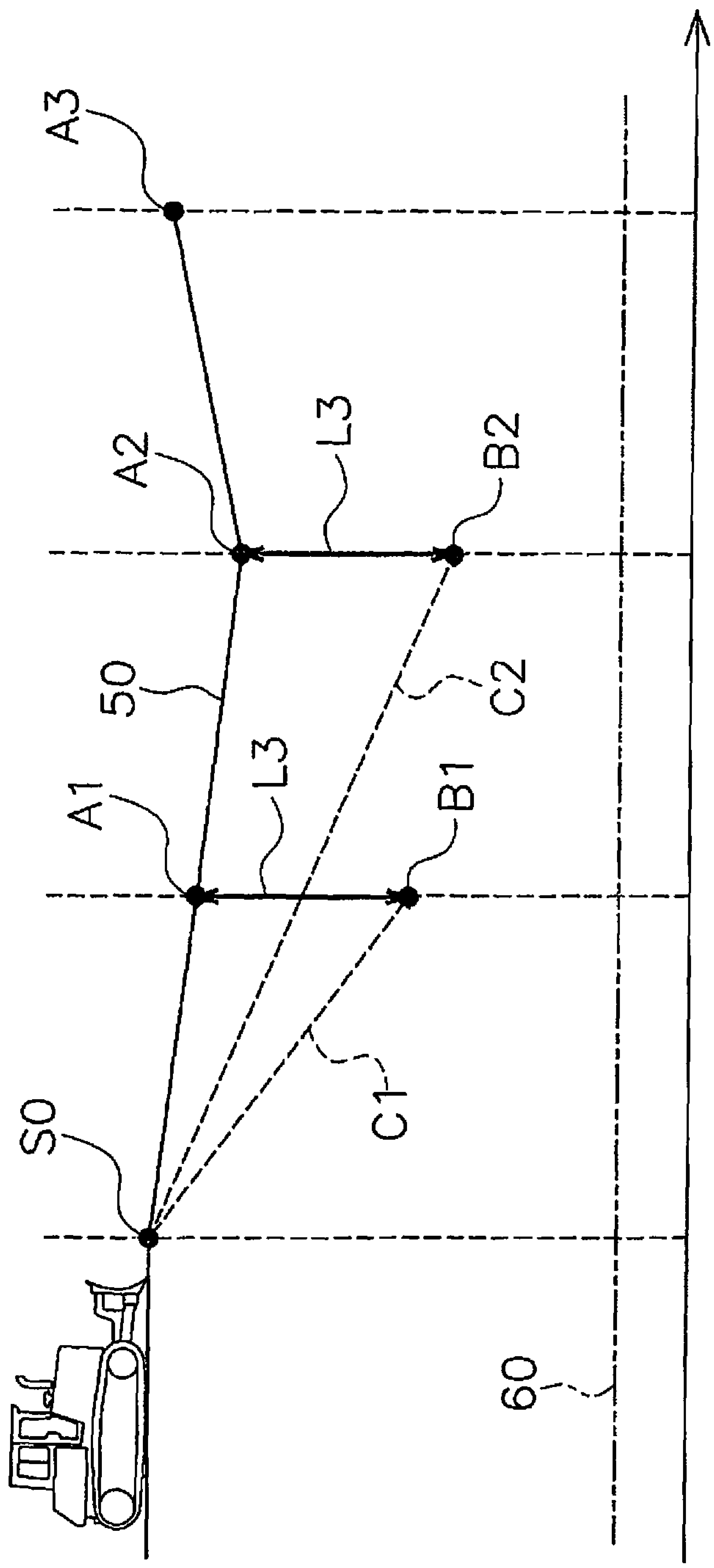

FIG. 10

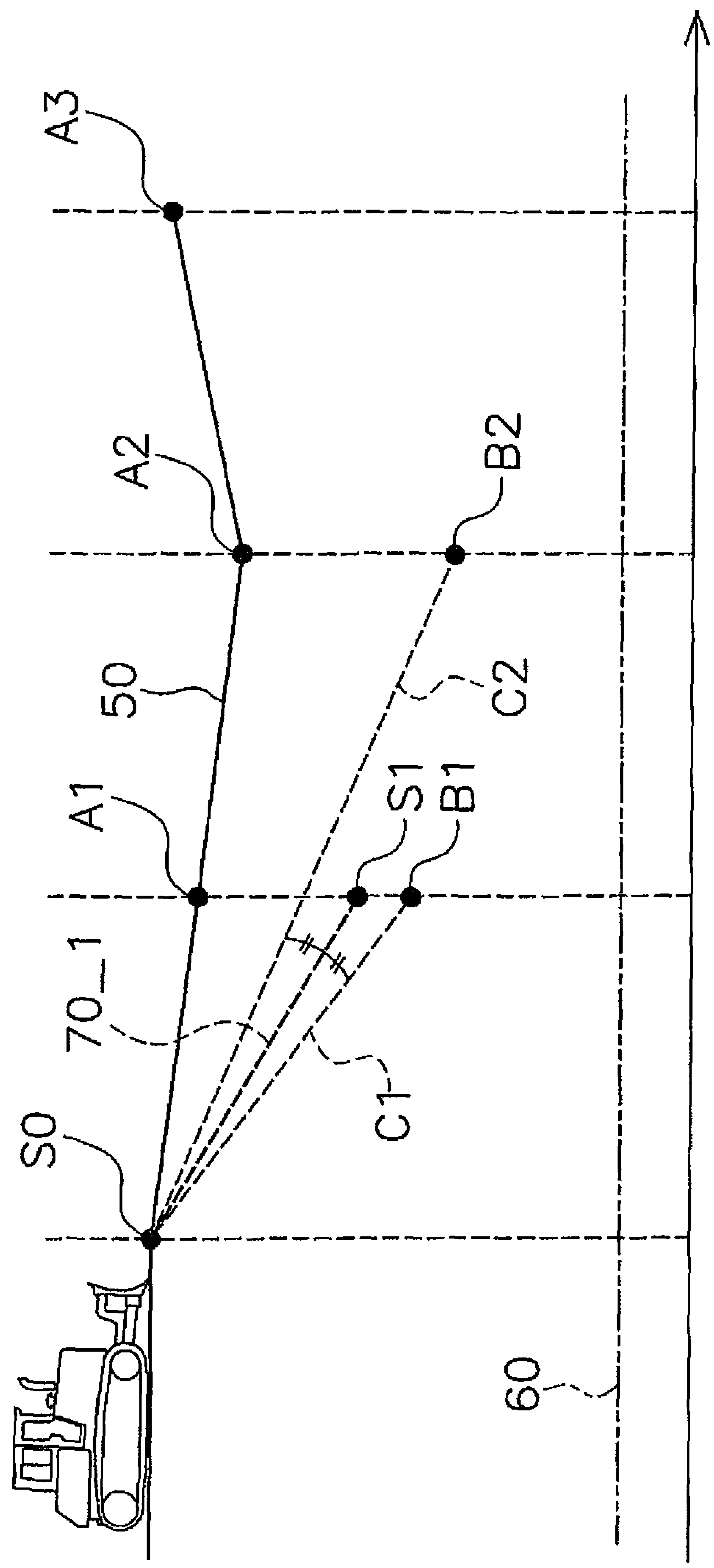

FIG. 11

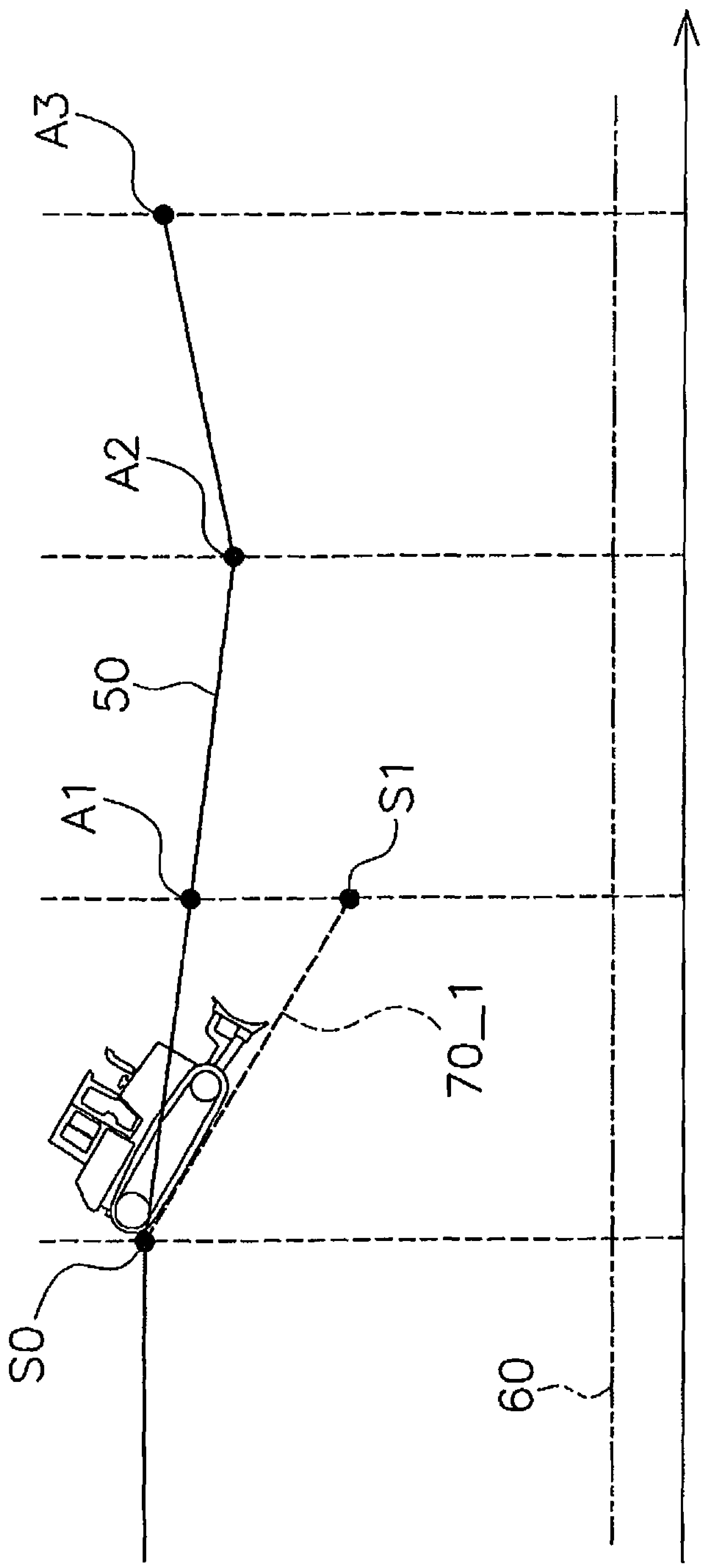

FIG. 12

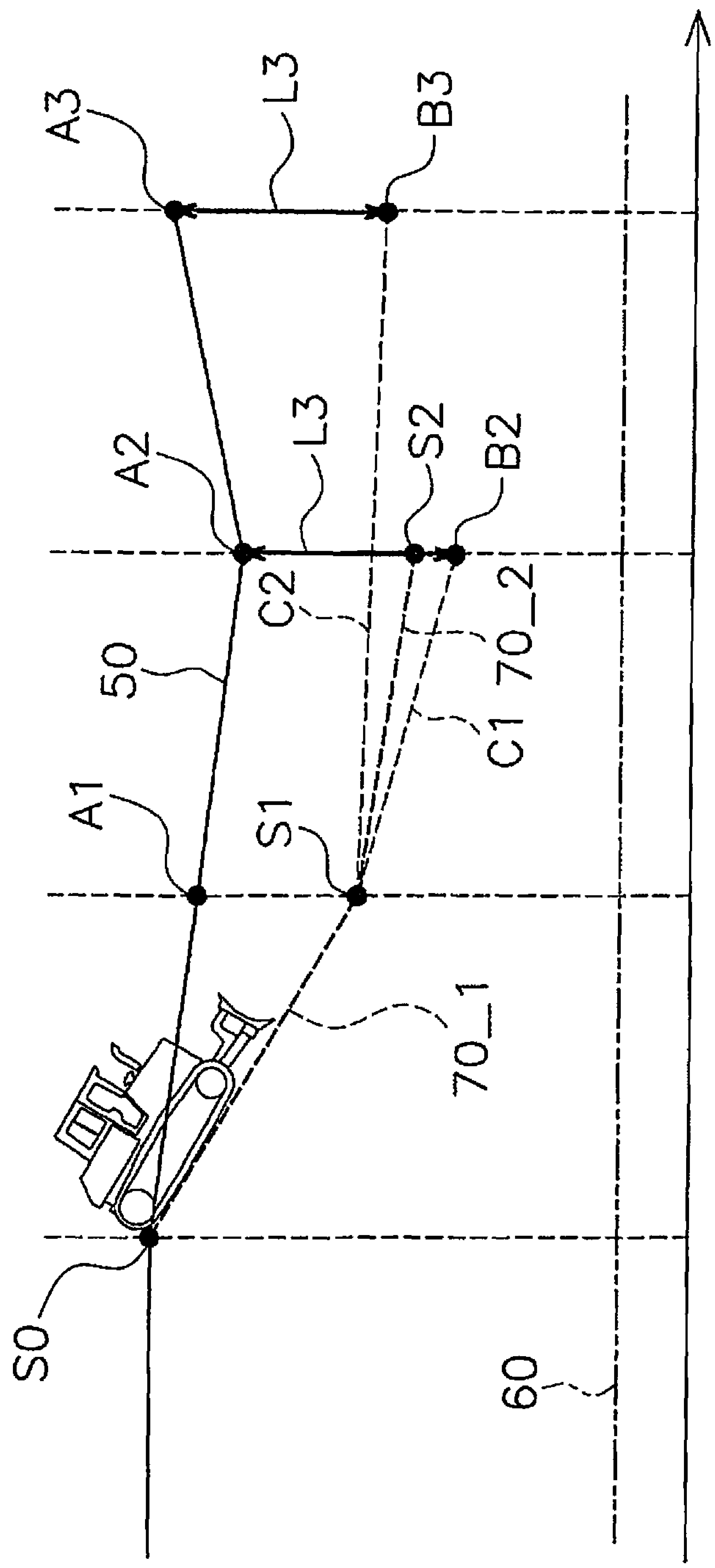

FIG. 13

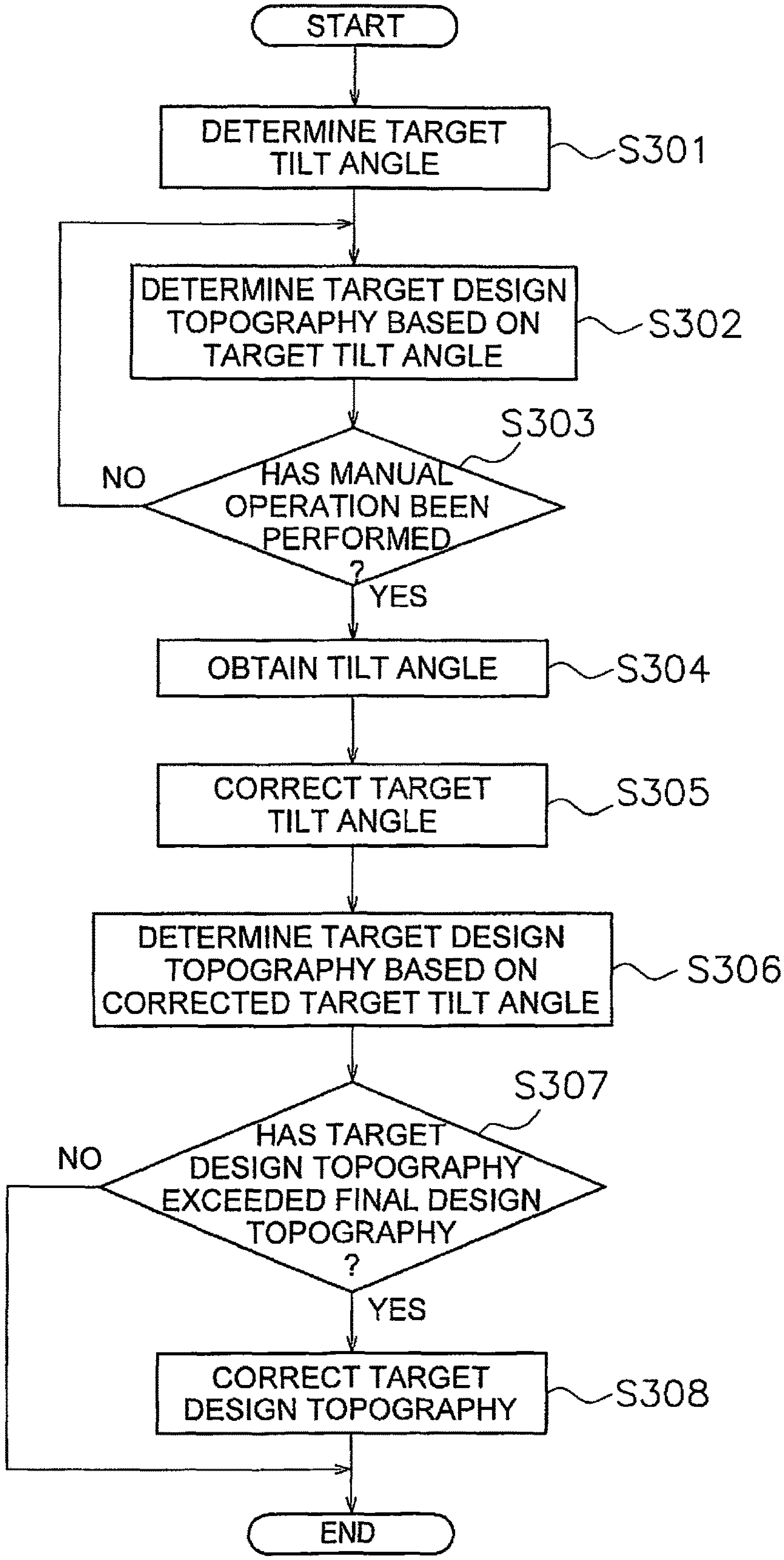
START
DETERMINE TARGET TILT ANGLE
S301
DETERMINE TARGET DESIGN TOPOGRAPHY BASED ON TARGET TILT ANGLE
S302
S303
HAS MANUAL OPERATION BEEN PERFORMED ?
NO
YES
OBTAIN TILT ANGLE
S304
CORRECT TARGET TILT ANGLE
S305
DETERMINE TARGET DESIGN TOPOGRAPHY BASED ON CORRECTED TARGET TILT ANGLE
S306
S307
HAS TARGET DESIGN TOPOGRAPHY EXCEEDED FINAL DESIGN TOPOGRAPHY ?
NO
YES
CORRECT TARGET DESIGN TOPOGRAPHY
S308
END

FIG. 14

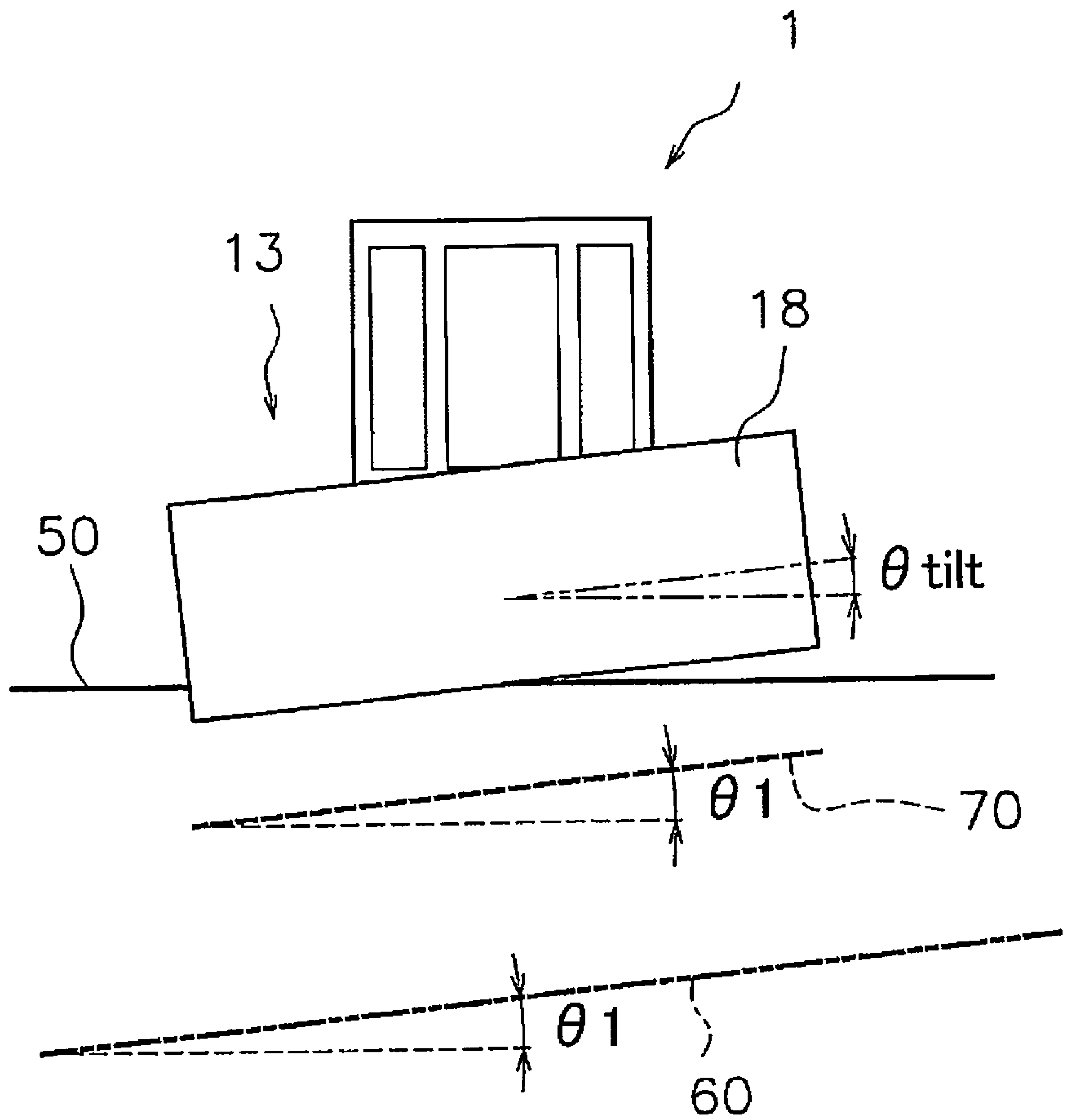

FIG. 15

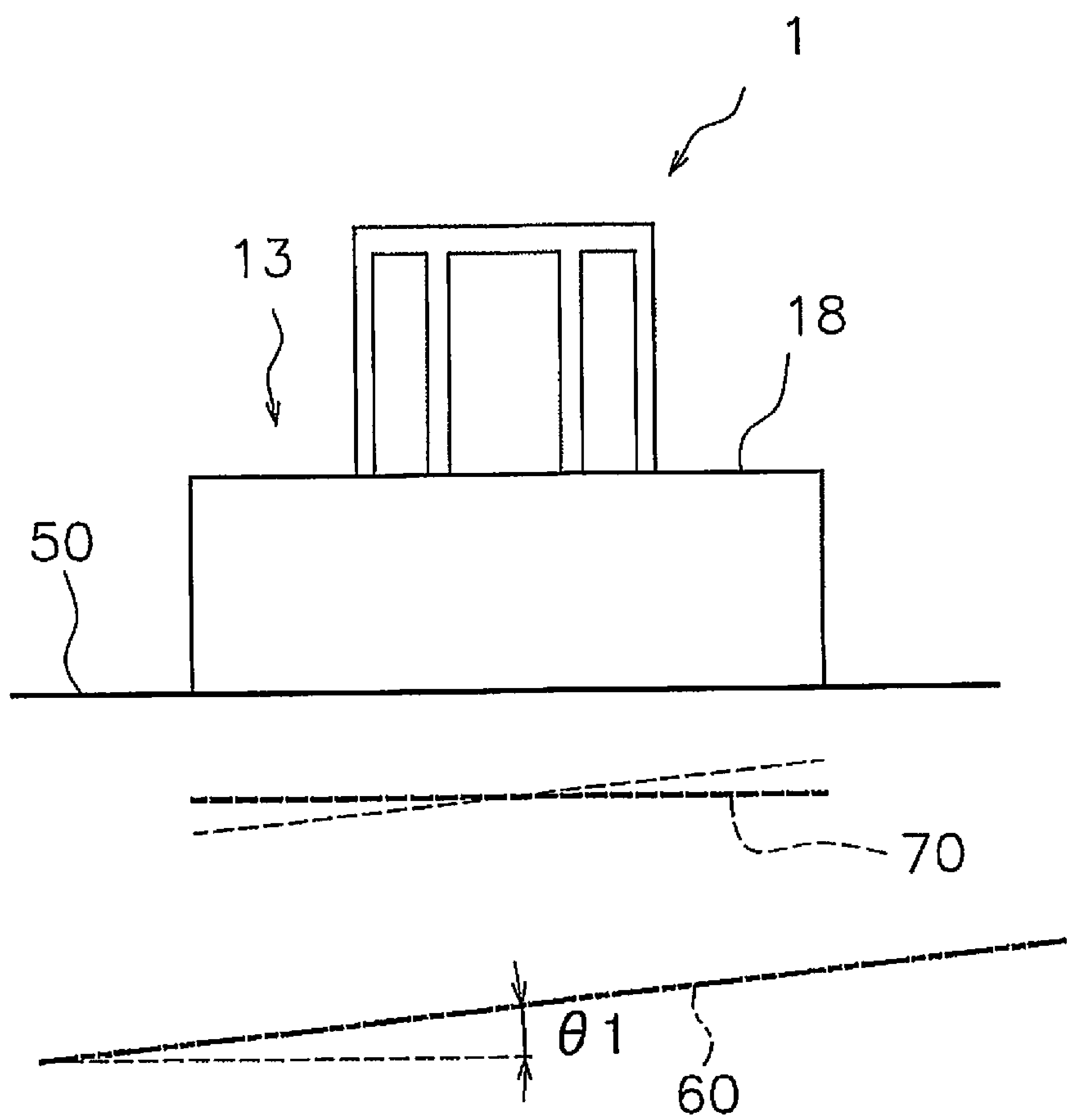

FIG. 16

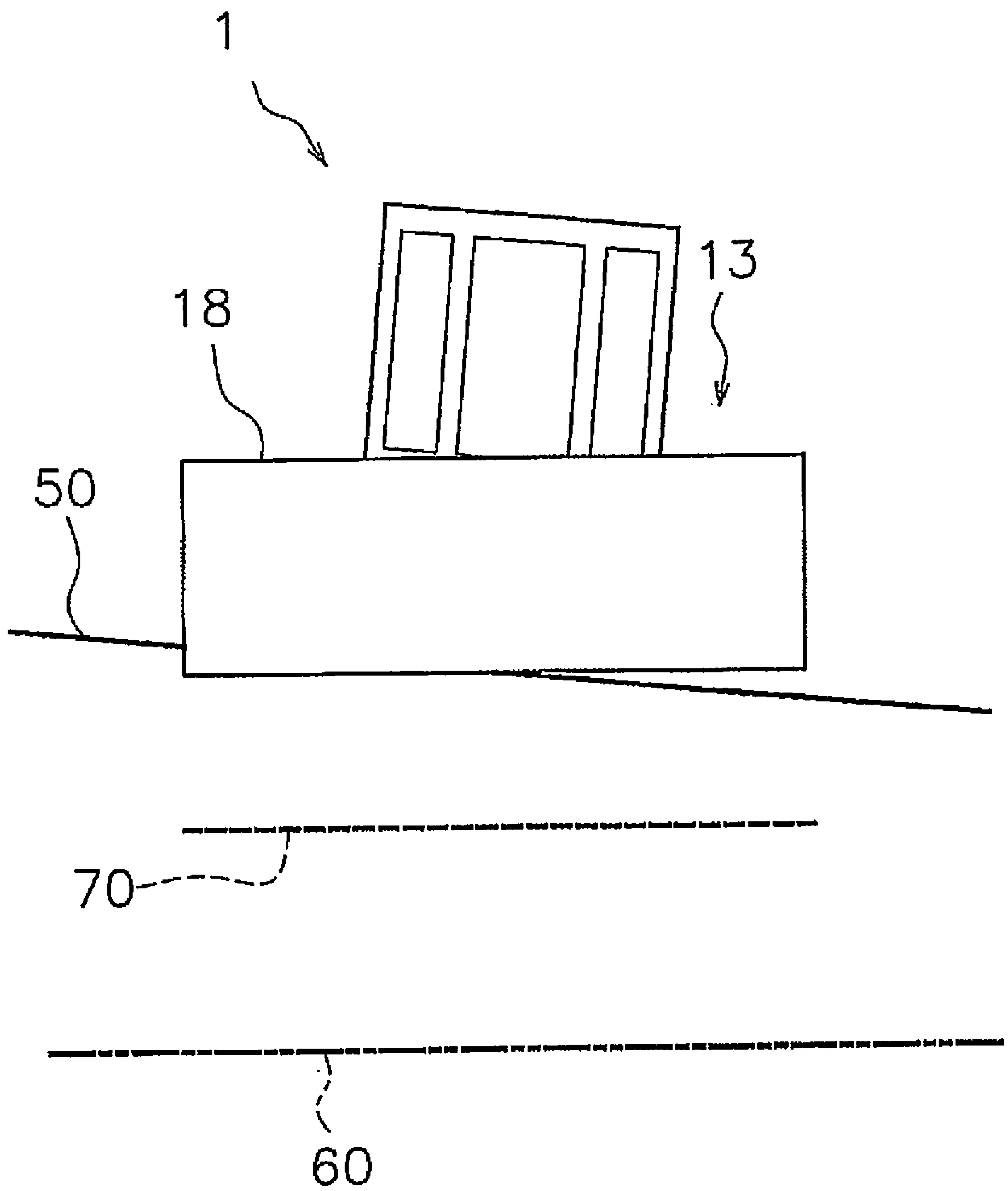

FIG. 17

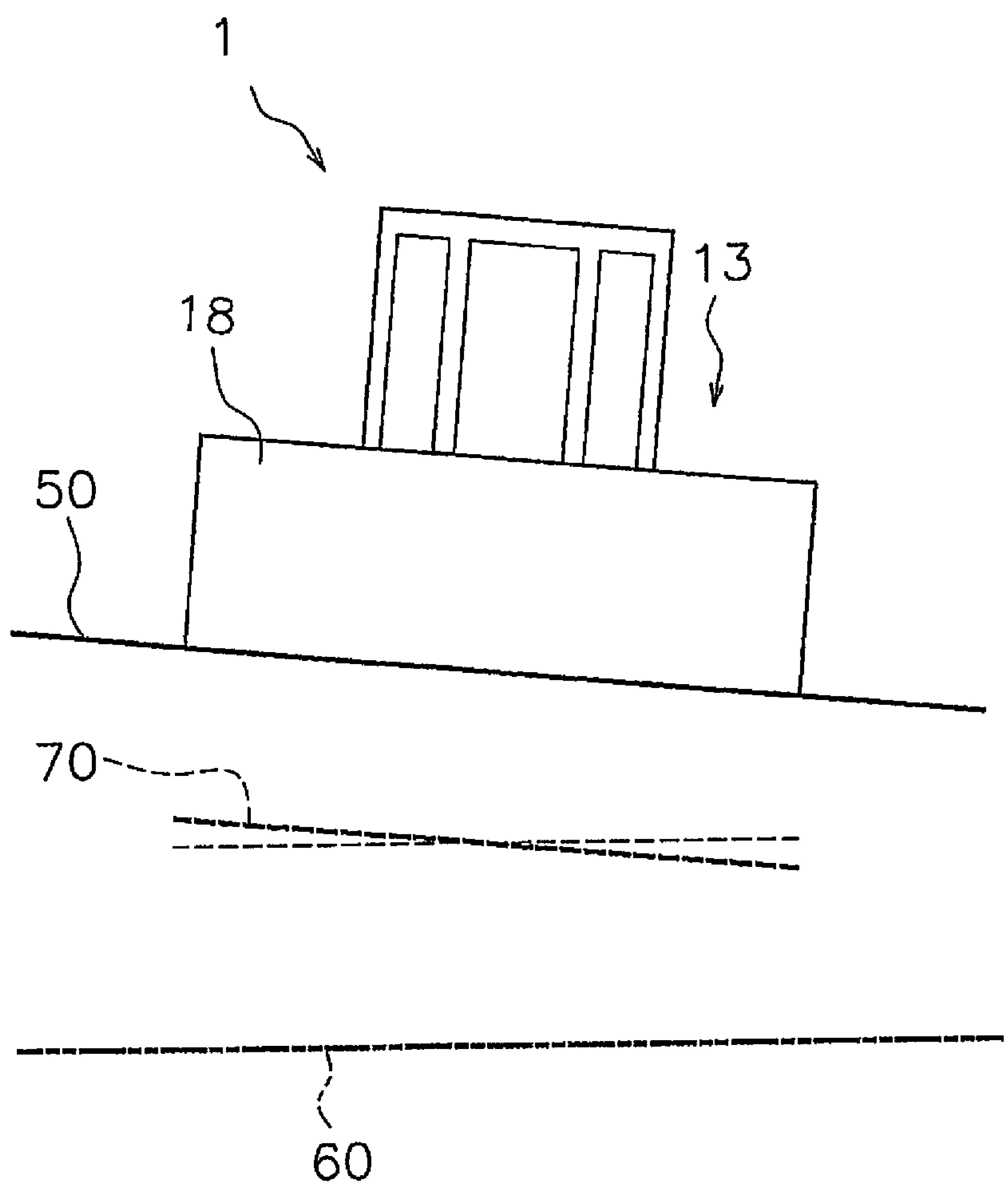

FIG. 18

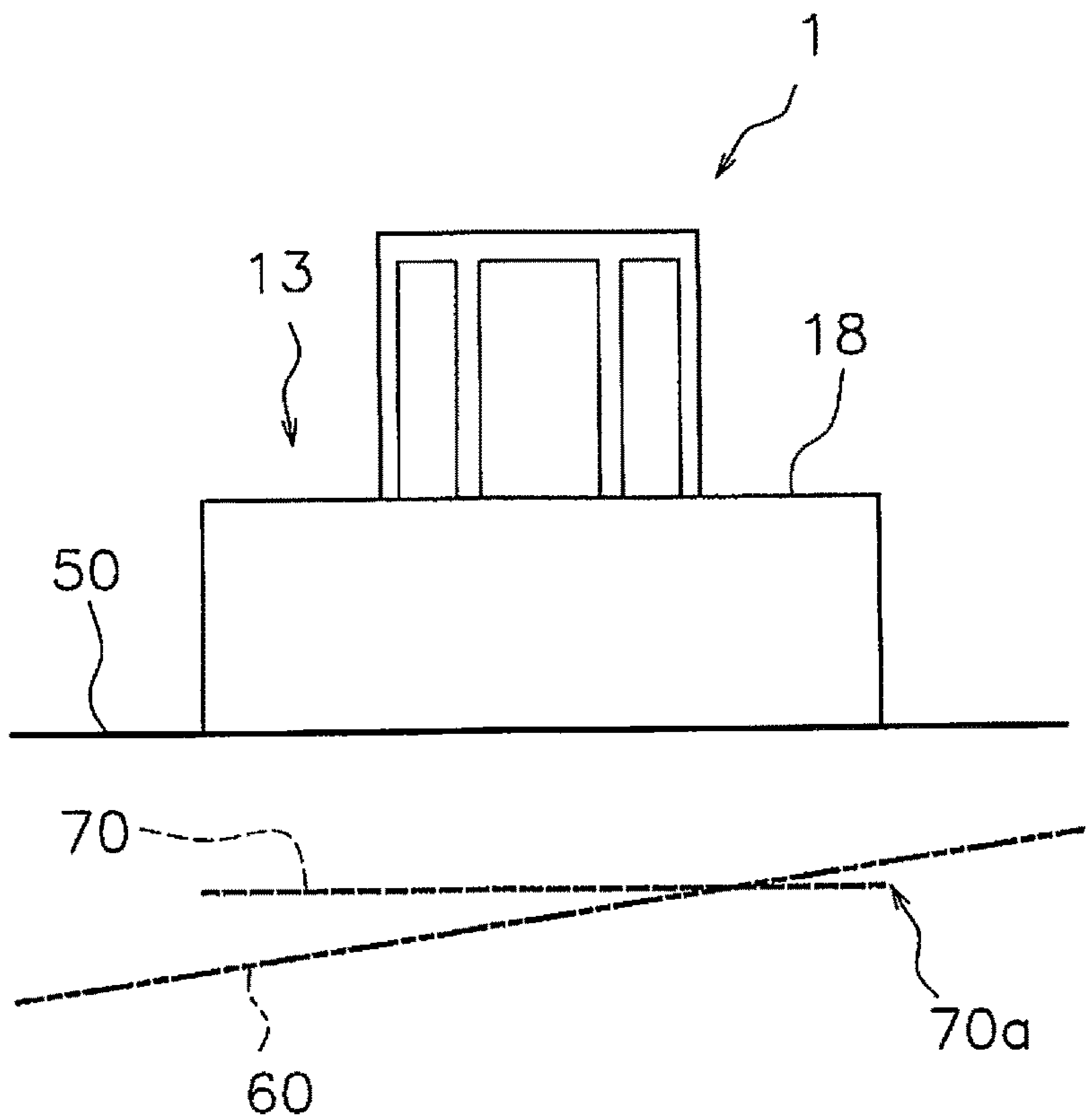

FIG. 19

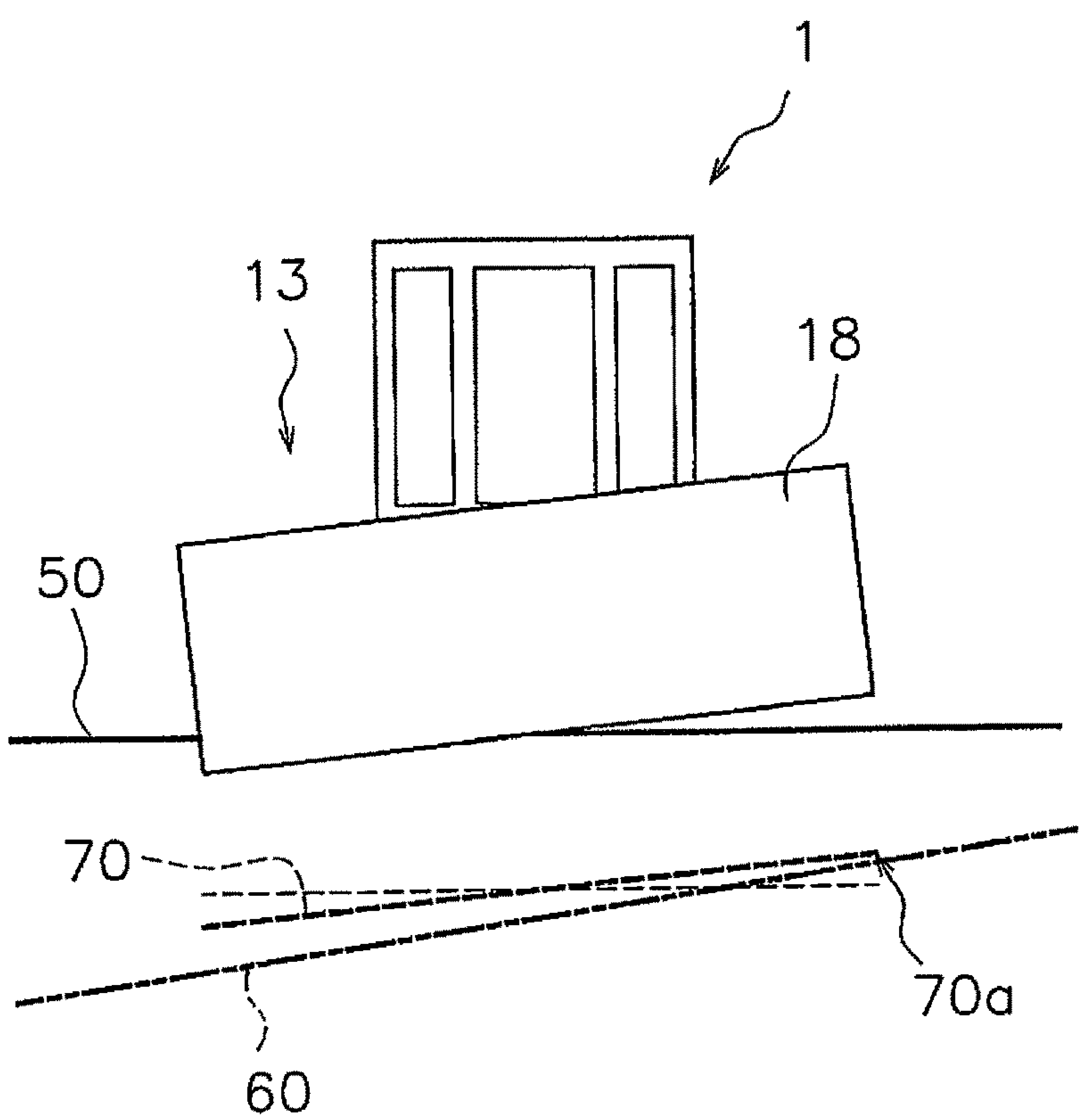

FIG. 20

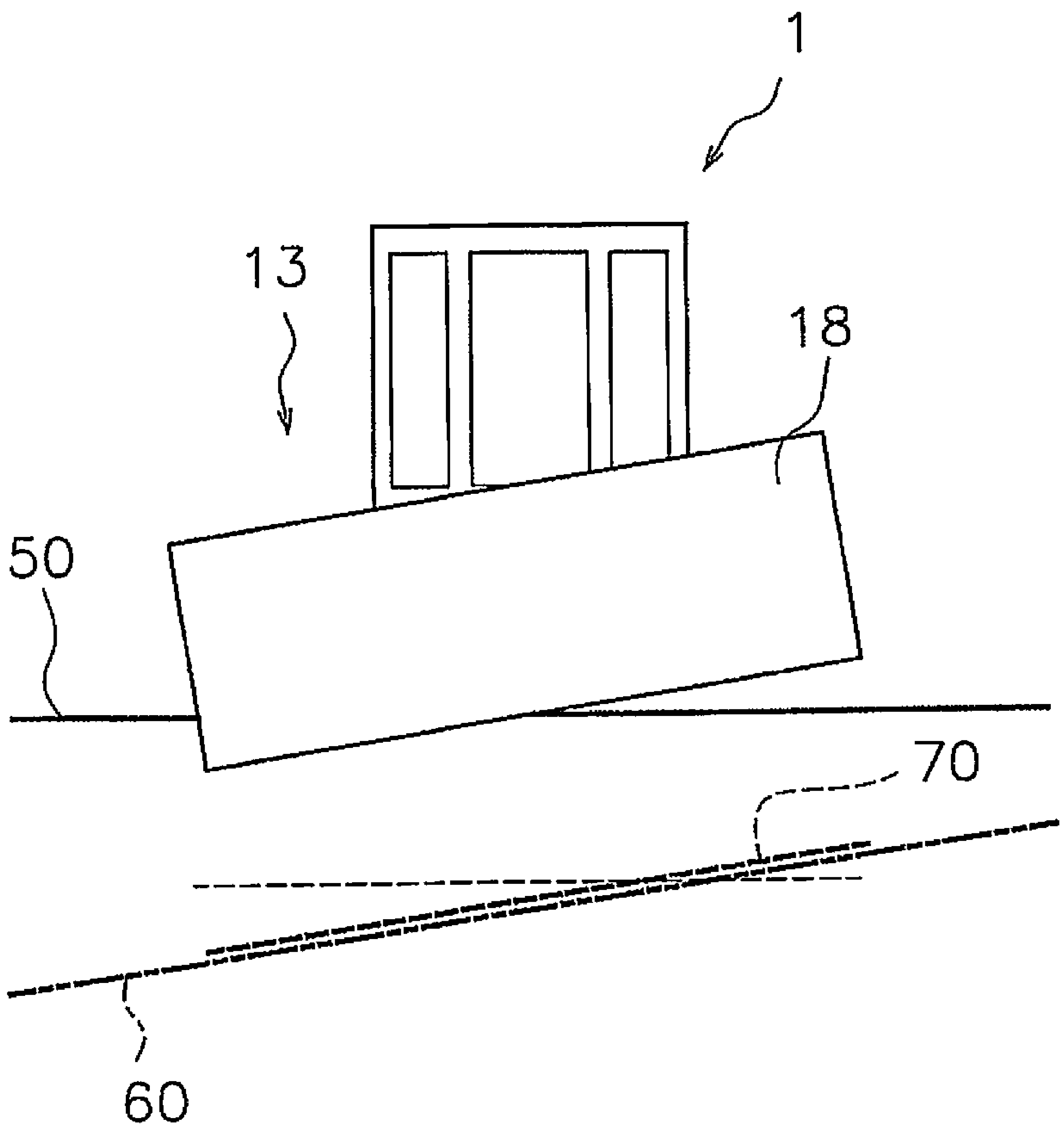

FIG. 21

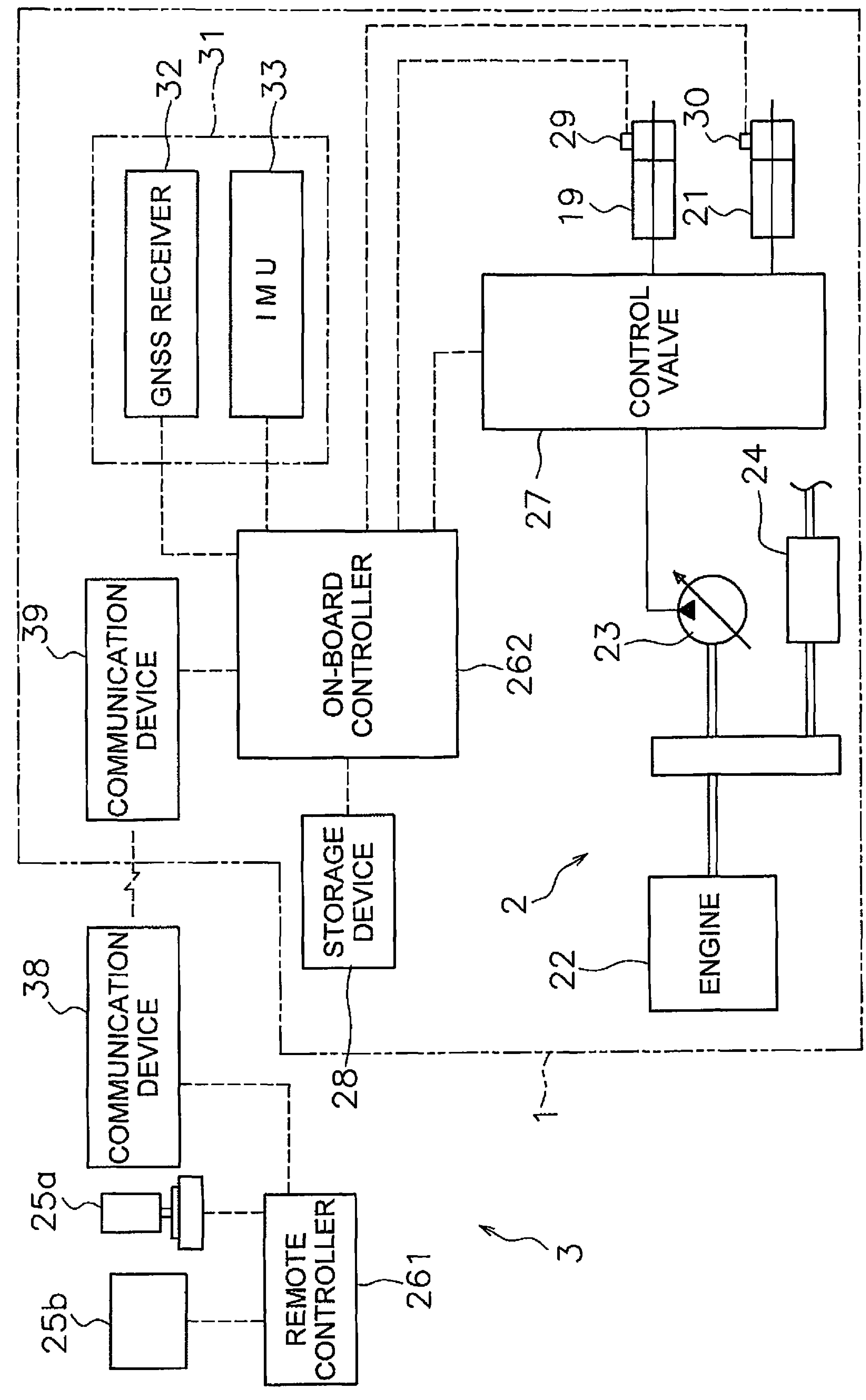
GNSS RECEIVER
IMU
CONTROL VALVE
ON-BOARD CONTROLLER
COMMUNICATION DEVICE
COMMUNICATION DEVICE
STORAGE DEVICE
ENGINE
REMOTE CONTROLLER
1
2
3
19
21
22
23
24
25a
25b
27
28
29
30
31
32
33
38
39
261
262

FIG. 22

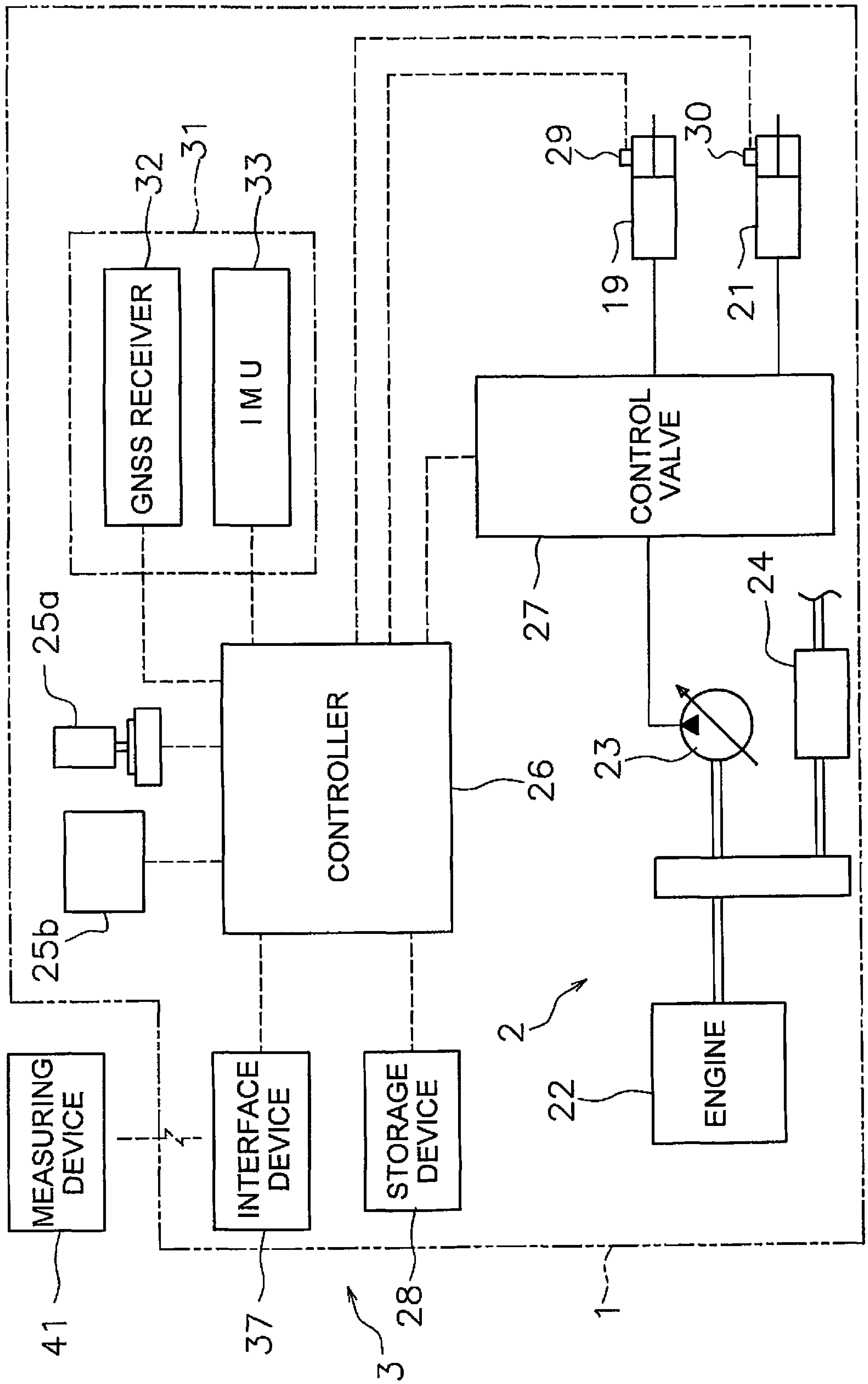
GNSS RECEIVER
IMU
CONTROLLER
CONTROL VALVE
ENGINE
MEASURING DEVICE
INTERFACE DEVICE
STORAGE DEVICE
1
2
3
19
21
22
23
24
25a
25b
26
27
28
29
30
31
32
33
37
41

FIG. 23

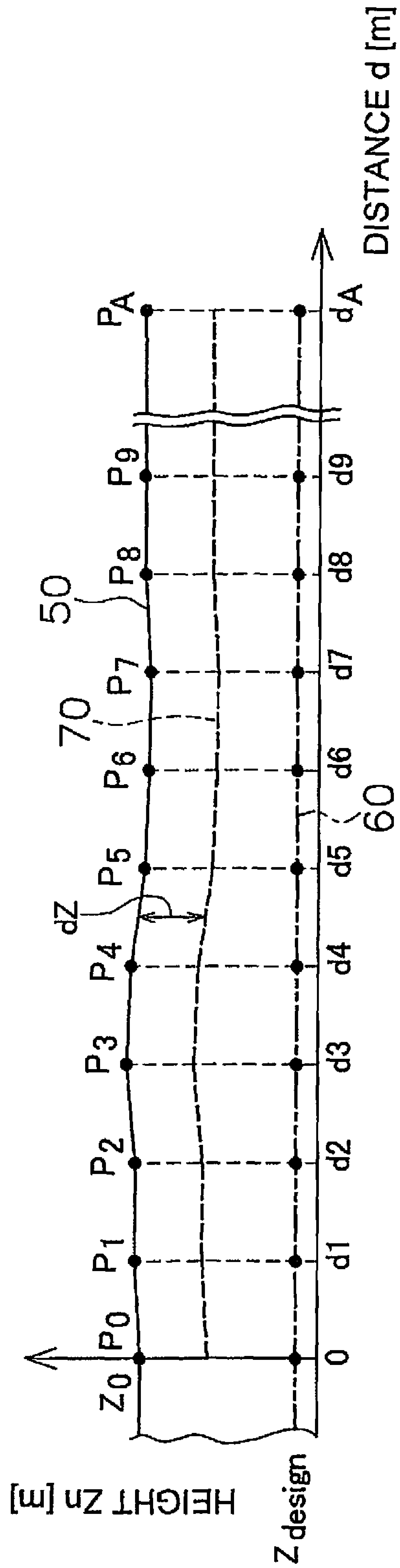
DISTANCE d [m]
HEIGHT Zn [m]
Z design
Z0
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
PA
dZ
50
60
70
0
d1
d2
d3
d4
d5
d6
d7
d8
d9
dA

FIG. 24

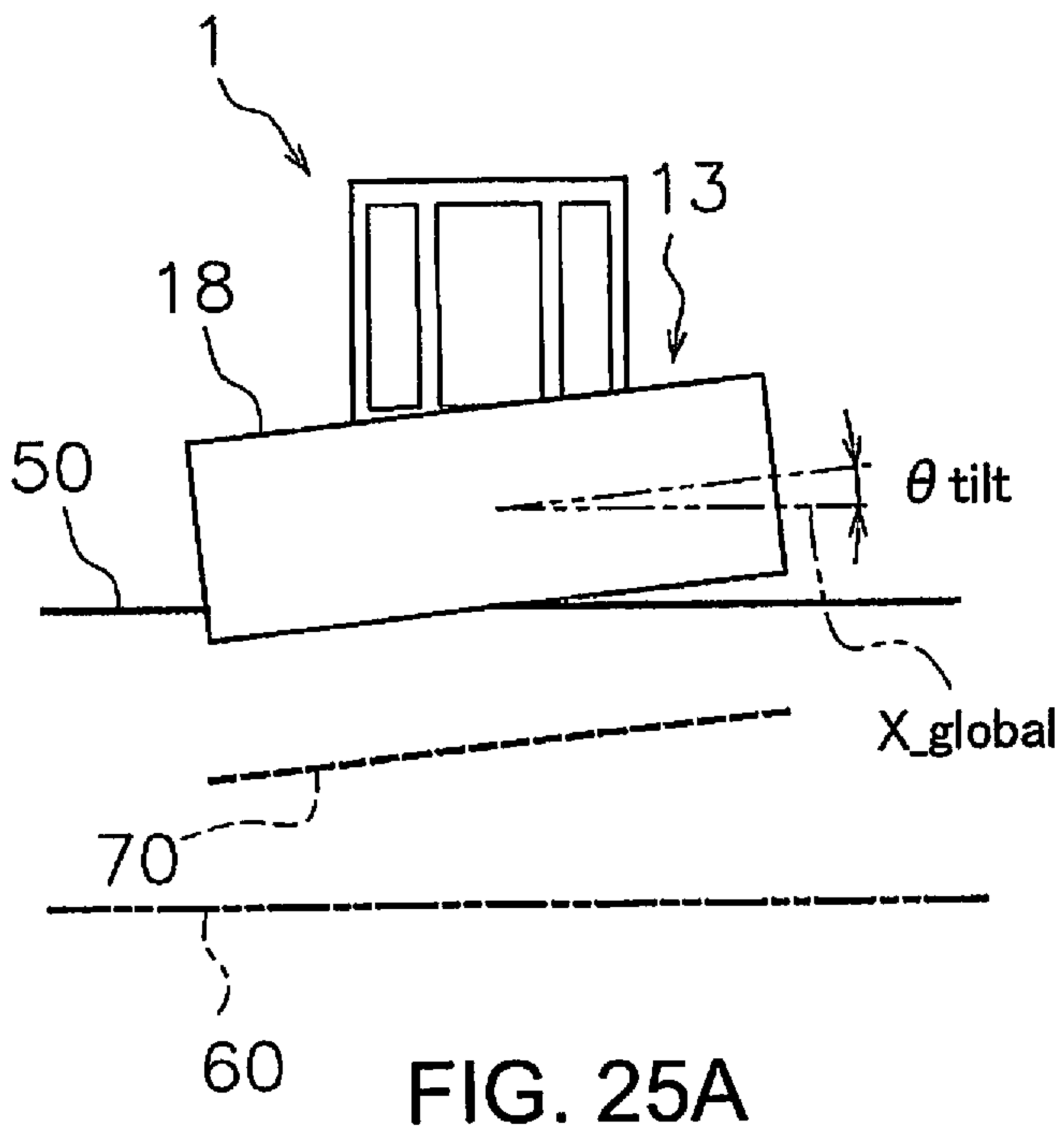

FIG. 25A

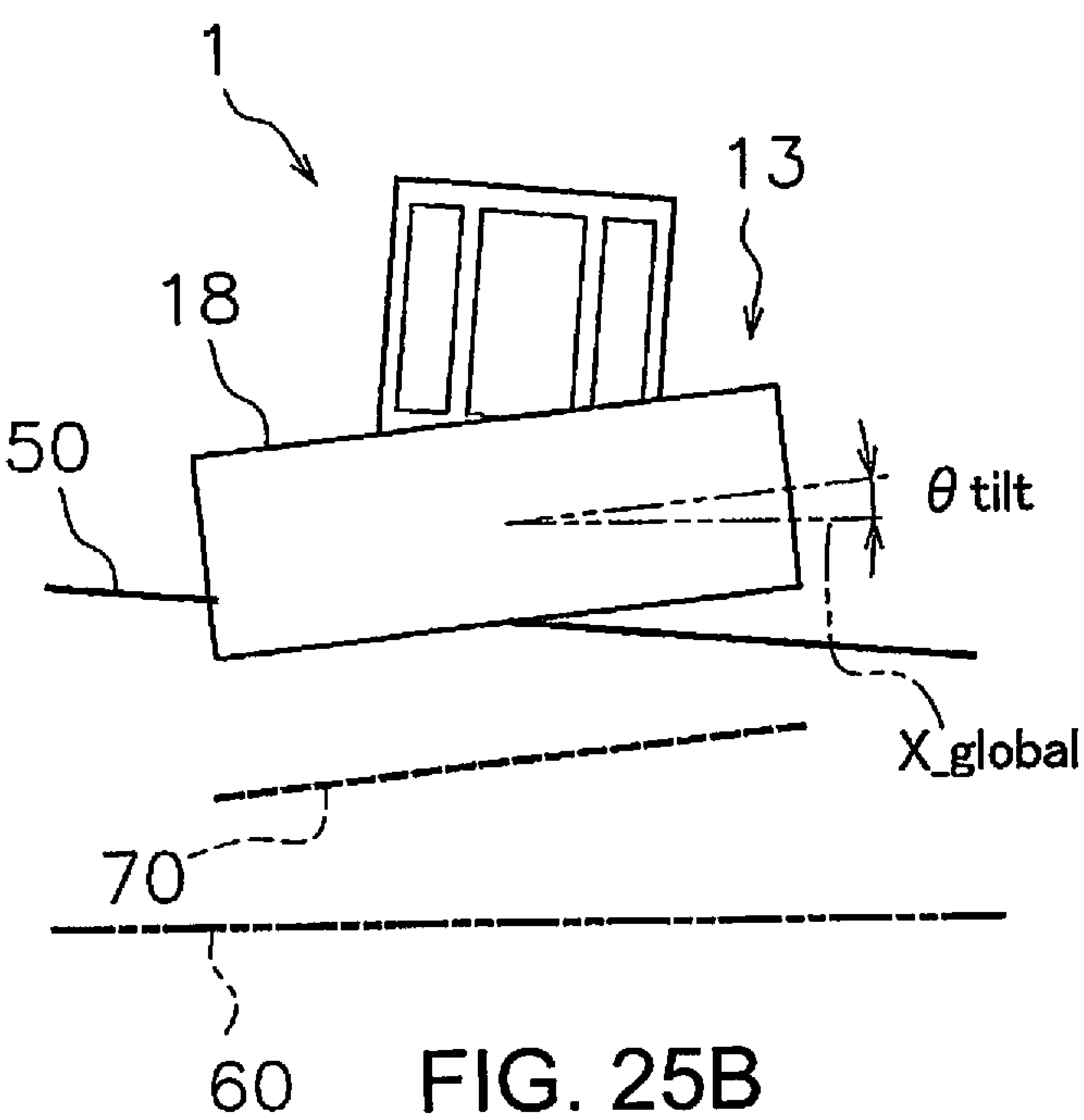

FIG. 25B

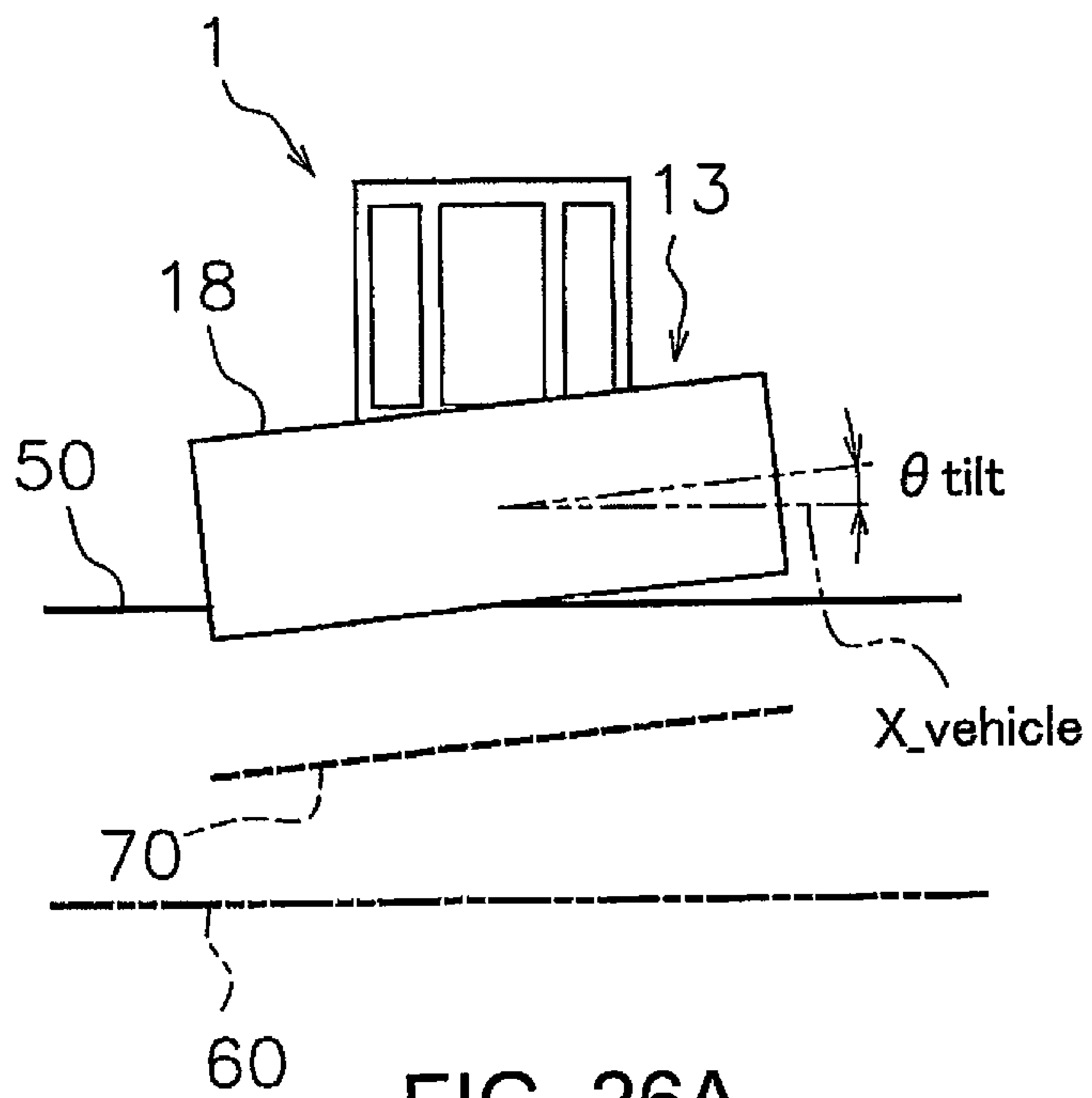

FIG. 26A

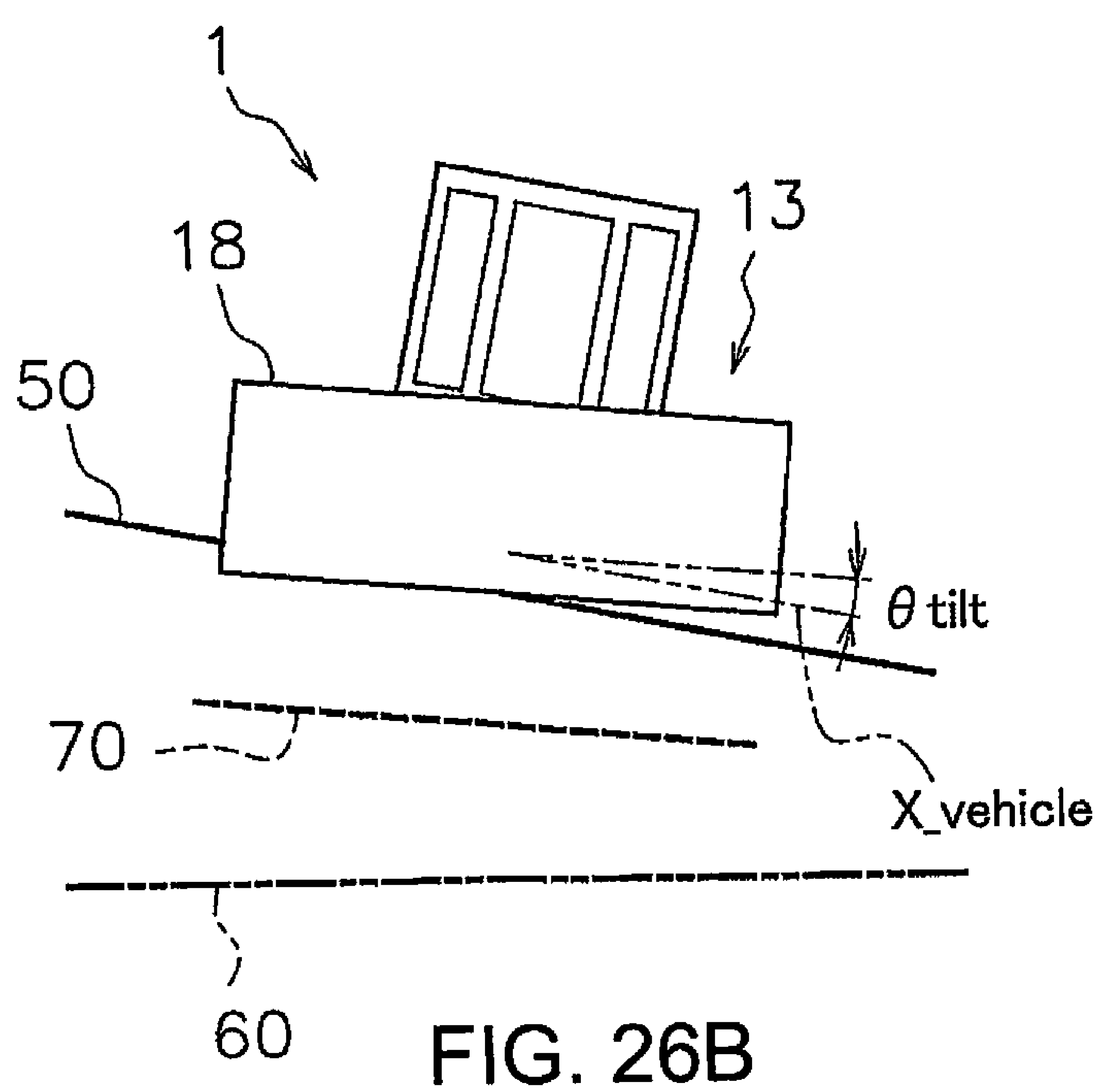

FIG. 26B

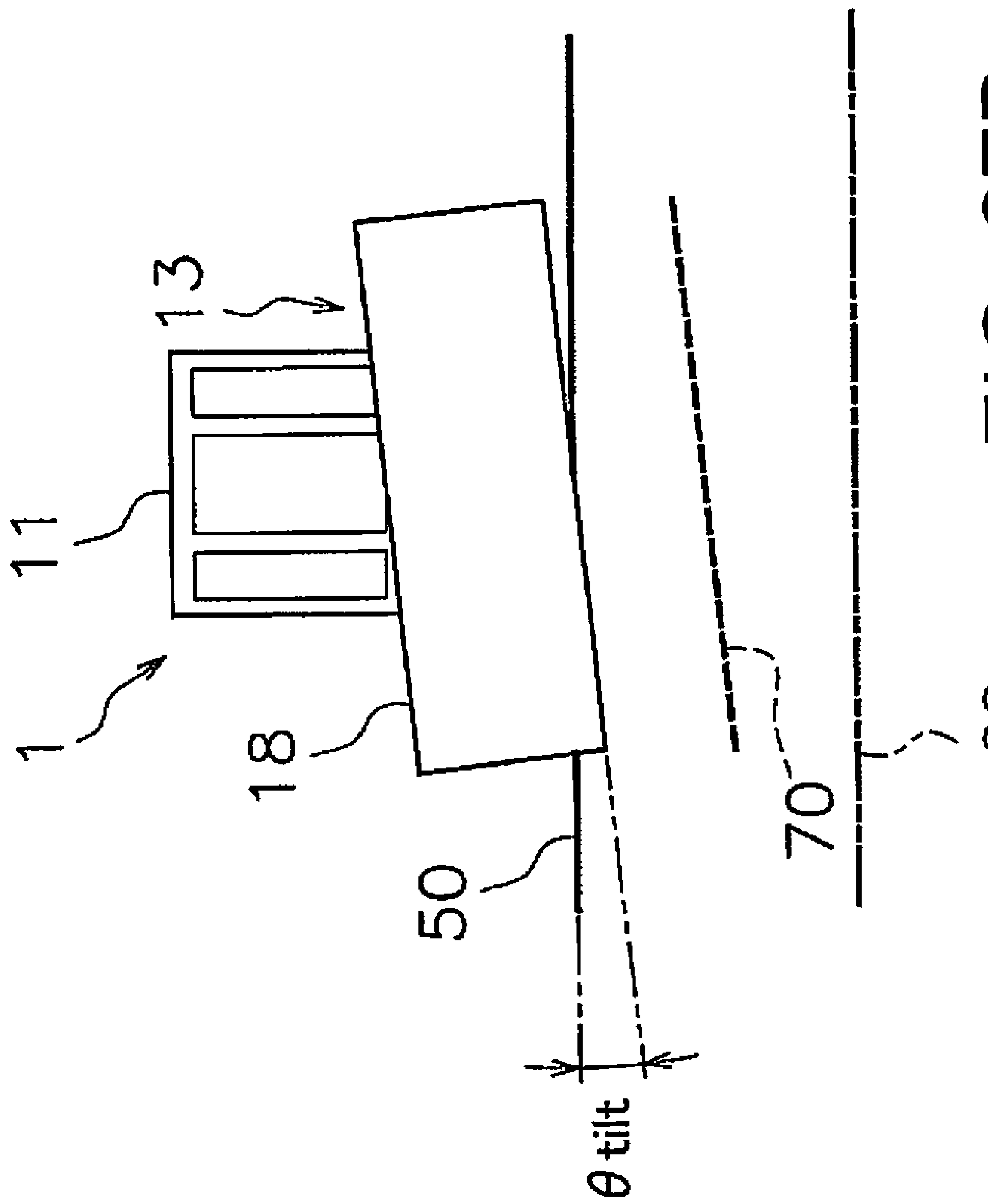

FIG. 27B

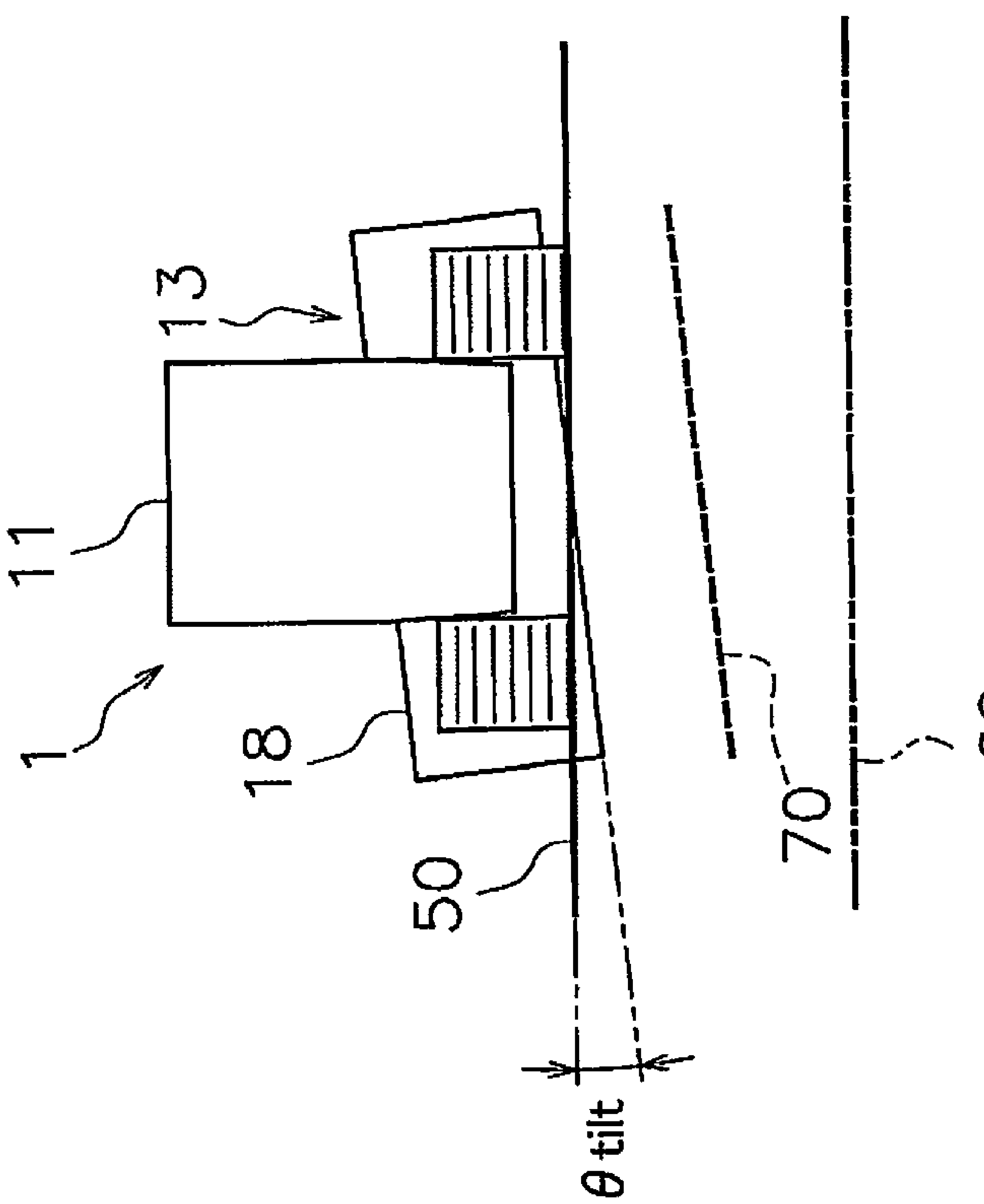

FIG. 27A

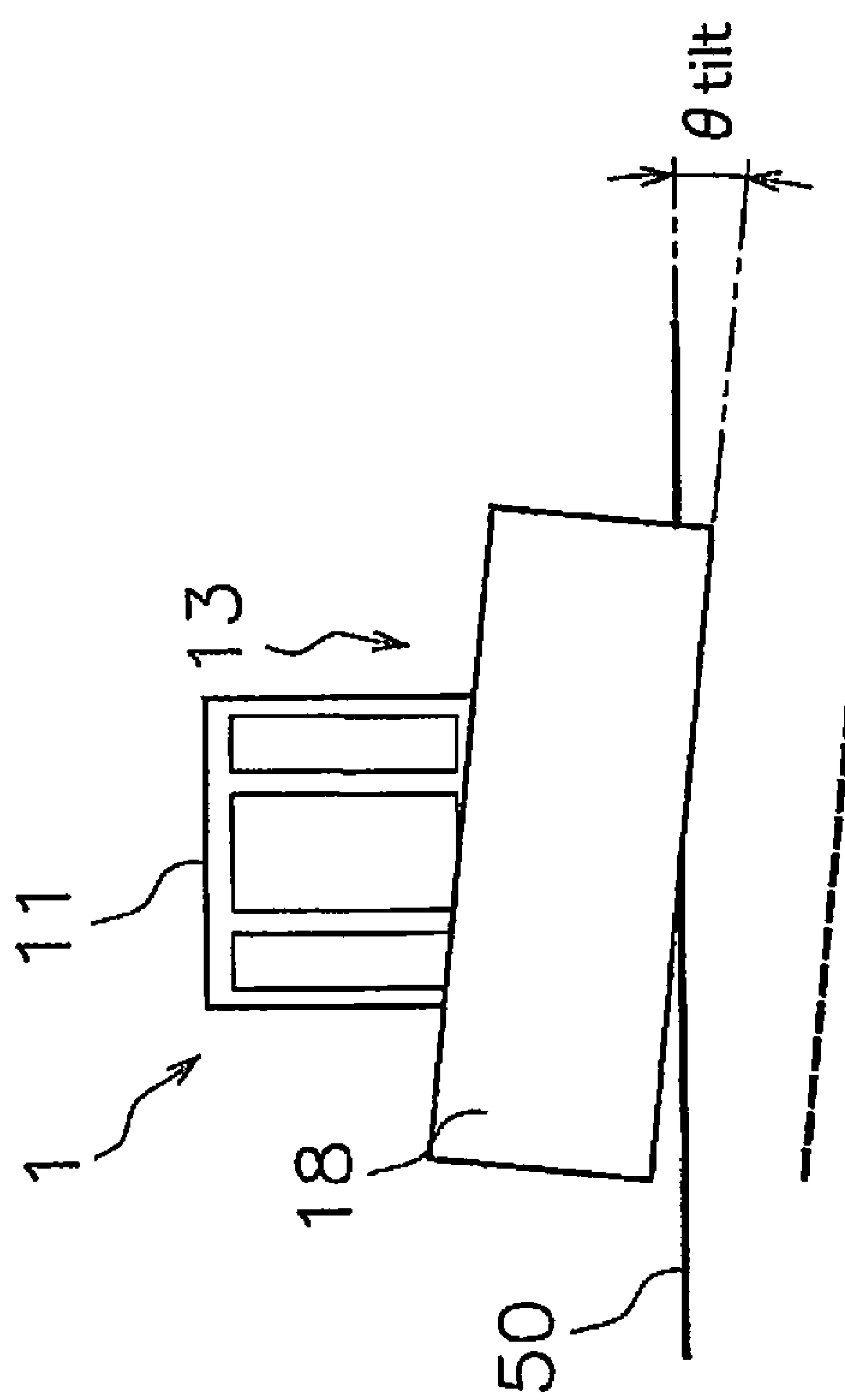

FIG. 28B

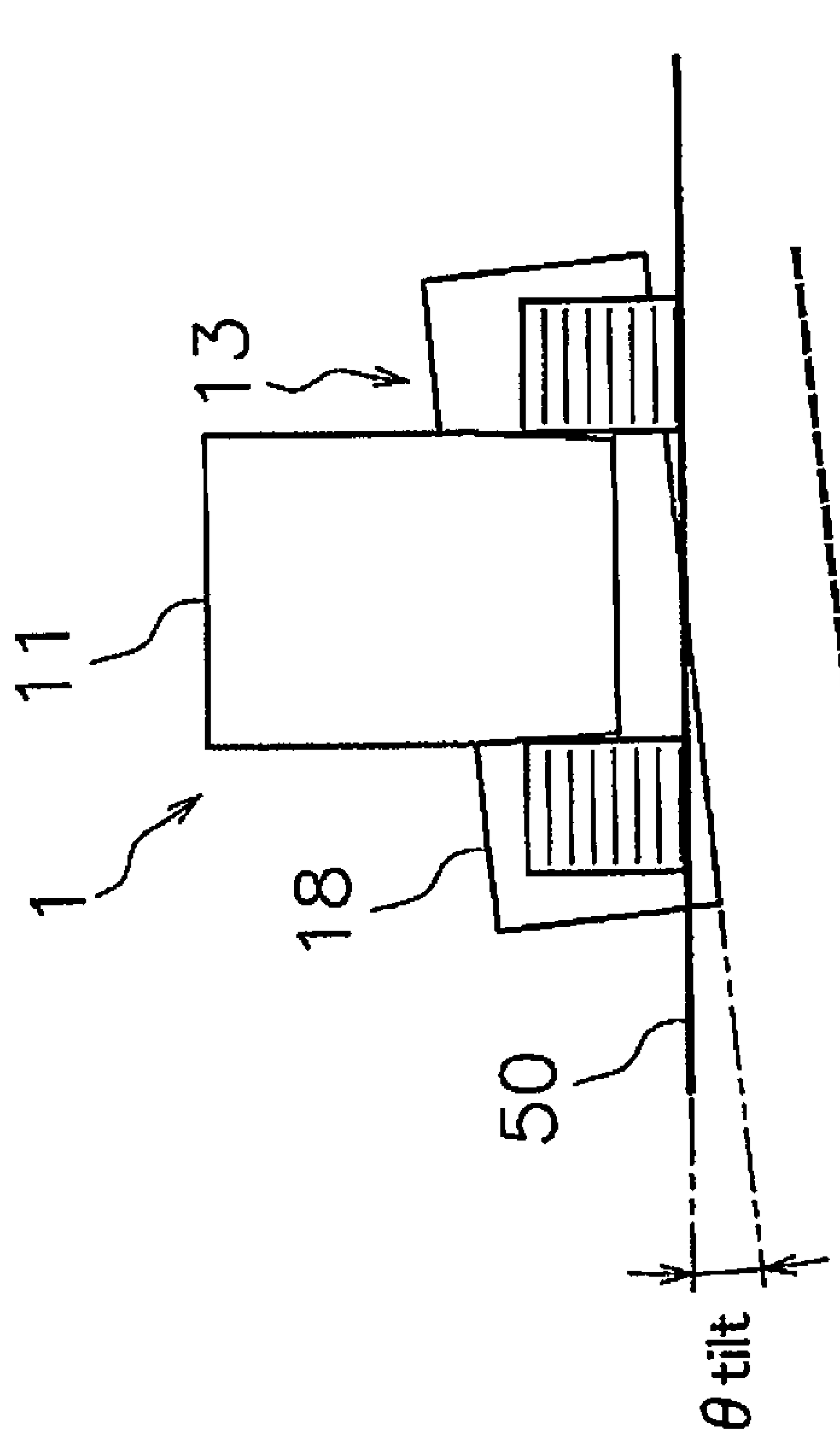

FIG. 28A

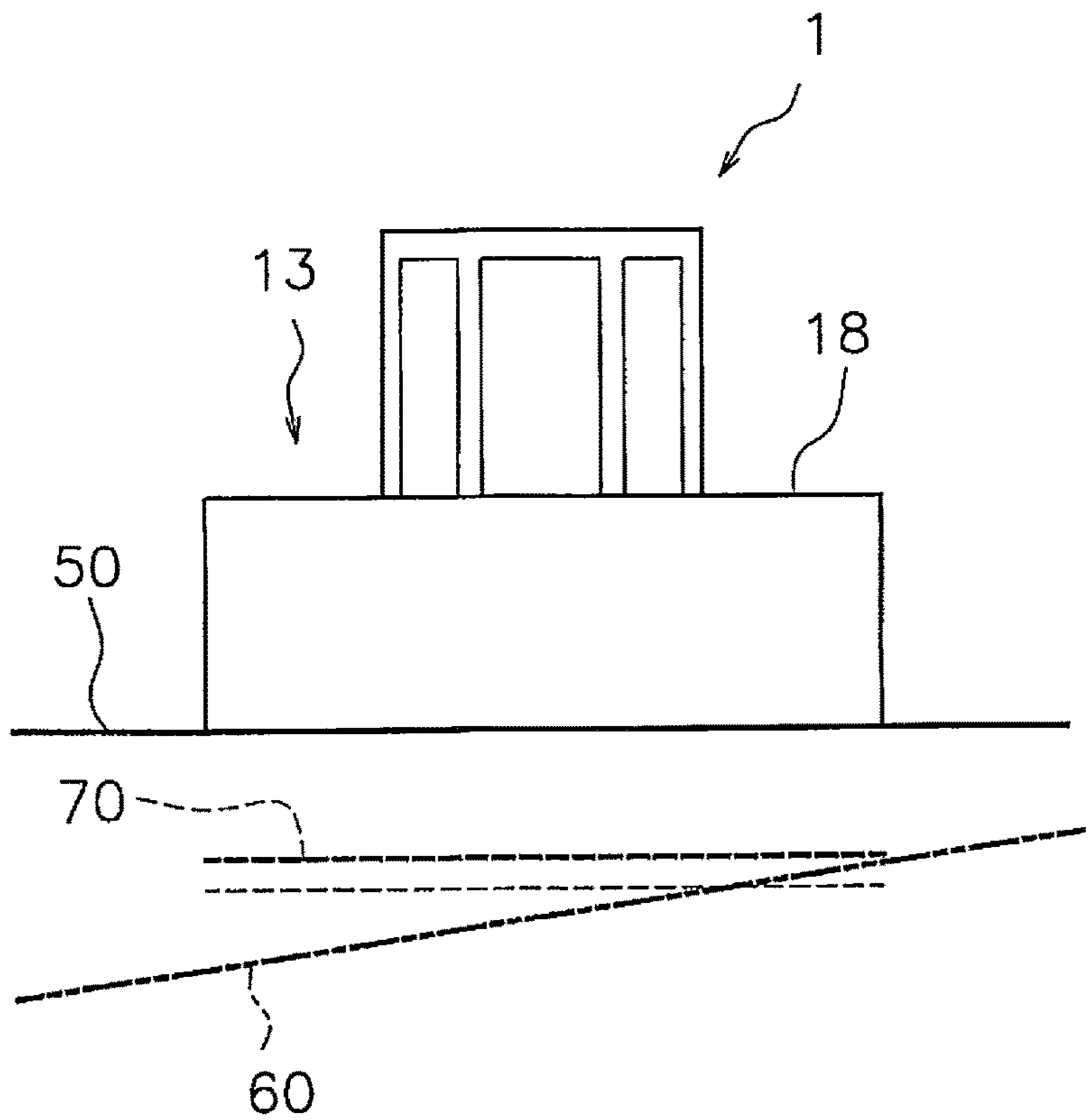

FIG. 29

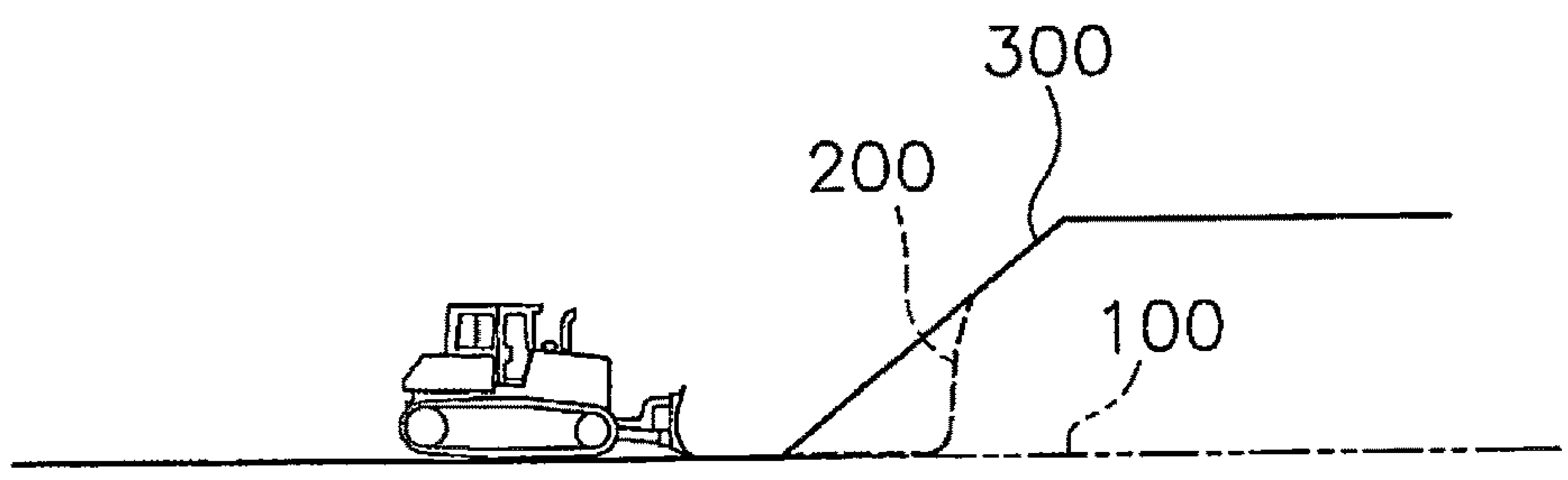

FIG. 30

CONTROL SYSTEM FOR WORK VEHICLE, METHOD, AND WORK VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National stage application of International Application No. PCT/JP2019/006101, filed on Feb. 19, 2019. This U.S. National stage application claims priority under 35 U.S.C. § 119(a) to Japanese Patent Application No. 2018-062772, filed in Japan on Mar. 28, 2018, the entire contents of which are hereby incorporated herein by reference.

BACKGROUND

Field of the Invention

The present invention relates to a control system for a work vehicle, a method, and a work vehicle.

Background Information

A control for automatically adjusting the position of a work implement such as a blade has been conventionally proposed for work vehicles such as bulldozers or graders and the like. For example, Japanese Patent Publication No. 5247939 describes automatically adjusting a blade by controlling the load so that the load applied to the blade matches a target load during excavating work.

SUMMARY

According to the abovementioned conventional control, the occurrence of shoe slip can be suppressed by raising the blade when the load on the blade becomes excessive. As a result, work can be performed with good efficiency.

However, as illustrated in FIG. **30**, first the blade is controlled so as to follow a design topography **100** in the conventional control. Thereafter, when the load on the blade becomes large, the blade is raised due to the load control (see the locus **200** of the blade in FIG. **30**). Therefore, when the blade is in a position that is deep in the design topography **100** with respect to the actual topography **300**, the load applied to the blade increases very quickly whereby the blade may be raised very quickly. In this case, because the terrain is formed with large undulations, it may be difficult to carry out excavating work smoothly. Moreover, there is a concern that the excavated terrain may easily become rough and the quality of the finish may decrease.

An object of the present invention is to cause a work vehicle to perform work efficiently and with a good finish quality with automatic control.

A first aspect is a control system for a work vehicle including a work implement, the control system including an operating device and a controller. The operating device outputs an operation signal indicative of an operation by an operator. The controller communicates with the operating device and controls the work implement. The controller is programmed so as to execute the following processes. The controller determines a target design topography indicative of a target topography. The controller generates a command signal to operate the work implement in accordance with the target design topography. When a tilt angle of the work implement is changed due to the operation of the operating device, the controller corrects the tilt angle of the work implement in accordance with the changed tilt angle.

A second aspect is a method executed by the controller for controlling a work vehicle including a work implement, the method including the following processes. A first process includes determining a target design topography indicative of a target topography. A second process includes generating a command signal to operate the work implement in accordance with the target design topography. A third process includes receiving an operation signal indicative of an operation by an operator, from the operating device. A fourth process includes, when a tilt angle of the work implement is changed with the operation of the operating device, correcting the tilt angle of the work implement in response to the changed tilt angle.

A third aspect is a work vehicle, the work vehicle including a work implement, an operating device, and a controller. The operating device outputs an operation signal indicative of an operation by an operator. The controller receives the operation signal and controls the work implement. The controller is programmed to execute the following processing. The controller determines a target design topography indicative of a target topography. The controller generates a command signal to operate the work implement in accordance with the target design topography. When a tilt angle of the work implement is changed with the operation of the operating device, the controller corrects the tilt angle of the work implement in response to the changed tilt angle.

According to the present invention, a work vehicle can be made to perform work efficiently and with a good finish quality with automatic control.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a side view of a work vehicle according to an embodiment.

FIG. **2** is a block diagram of a configuration of a drive system and a control system of the work vehicle.

FIG. **3** is a schematic side view of a configuration of the work vehicle.

FIG. **4** is a schematic front view of a configuration of the work vehicle.

FIG. **5** is a flow chart of an automatic control process of the work vehicle.

FIG. **6** illustrates examples of a final design topography, an actual topography, and a target design topography.

FIG. **7** is a flow chart of a process for determining the target design topography.

FIG. **8** illustrates a process for determining the target design topography.

FIG. **9** illustrates a process for determining the target design topography.

FIG. **10** illustrates a process for determining the target design topography.

FIG. **11** illustrates a process for determining the target design topography.

FIG. **12** illustrates a process for determining the target design topography.

FIG. **13** illustrates a process for determining the target design topography.

FIG. **14** is a flow chart of a process when a manual operation is introduced.

FIG. **15** illustrates a process for determining an initial value of a target tilt angle.

FIG. **16** illustrates a process for determining a changed target tilt angle.

FIG. **17** illustrates a process for determining an initial value of a target tilt angle.

FIG. **18** illustrates a process for determining a changed target tilt angle.

FIG. **19** illustrates a process for correcting the target design topography.

FIG. **20** illustrates a process for correcting the target design topography.

FIG. **21** illustrates a process for correcting the target design topography.

FIG. **22** is a block diagram of a configuration of a drive system and a control system of the work vehicle according to a first modified example.

FIG. **23** is a block diagram of a configuration of a drive system and a control system of the work vehicle according to a second modified example.

FIG. **24** illustrates a process for determining the target design topography according to another embodiment.

FIG. **25**A and FIG. **25**B illustrate a first example of a first tilt angle control.

FIG. **26**A and FIG. **26**B illustrate a first example of a second tilt angle control.

FIG. **27**A and FIG. **27**B illustrate a second example of the first tilt angle control.

FIG. **28**A and FIG. **28**B illustrate a second example of the second tilt angle control.

FIG. **29** illustrates a correction method for the target design topography according to another embodiment.

FIG. **30** illustrates excavation work according to the prior art.

DETAILED DESCRIPTION OF EMBODIMENT(S)

A work vehicle according to an embodiment is discussed hereinbelow with reference to the drawings. FIG. **1** is a side view of the work vehicle **1** according to an embodiment. The work vehicle **1** according to the present embodiment is a bulldozer. The work vehicle **1** includes a vehicle body **11**, a travel device **12**, and a work implement **13**.

The vehicle body **11** has an operating cabin **14** and an engine compartment **15**. An operator's seat that is not illustrated is disposed inside the operating cabin **14**. The engine compartment **15** is disposed in front of the operating cabin **14**. The travel device **12** is attached to a bottom part of the vehicle body **11**. The travel device **12** has a pair of left and right crawler belts **16**. Only the crawler belt **16** on the left side is illustrated in FIG. **1**. The work vehicle **1** travels due to the rotation of the crawler belts **16**.

The work implement **13** is attached to the vehicle body **11**. The work implement **13** has a lift frame **17**, a blade **18**, a lift cylinder **19**, and a tilt cylinder **21**. The lift frame **17** is attached to the vehicle body **11** in a manner that allows movement up and down centered on an axis X that extends in the vehicle width direction. The lift frame **17** supports the blade **18**.

The blade **18** is disposed in front of the vehicle body **11**. The blade **18** moves up and down accompanying the up and down movements of the lift frame **17**. The lift frame **17** may be attached to the travel device **12**. The lift cylinder **19** is coupled to the vehicle body **11** and the lift frame **17**. Due to the extension and contraction of the lift cylinder **19**, the lift frame **17** rotates up and down centered on the axis X. The tilt cylinder **21** is coupled to the lift frame **17** and the blade **18**. Due to the extension and contraction of the tilt cylinder **21**, the blade **18** rotates (referred to below as a "tilting motion") around an axis Z that extends in the front-back direction of the vehicle.

FIG. **2** is a block diagram of a configuration of a drive system **2** and a control system **3** of the work vehicle **1**. As illustrated in FIG. **2**, the drive system **2** includes an engine **22**, a hydraulic pump **23**, and a power transmission device **24**.

The hydraulic pump **23** is driven by the engine **22** to discharge hydraulic fluid. The hydraulic fluid discharged from the hydraulic pump **23** is supplied to the lift cylinder **19** and the tilt cylinder **21**. While only one hydraulic pump **23** is illustrated in FIG. **2**, a plurality of hydraulic pumps may be provided.

The power transmission device **24** transmits driving power from the engine **22** to the travel device **12**. The power transmission device **24** may be a hydrostatic transmission (HST), for example. Alternatively, the power transmission device **24** may be, for example, a transmission including a torque converter or a plurality of speed change gears.

The control system **3** includes an operating device **25***a*, an input device **25***b*, a controller **26**, a storage device **28**, and a control valve **27**. The operating device **25***a* and the input device **25***b* are disposed in the operating cabin **14**. The operating device **25***a* is a device for operating the work implement **13** and the travel device **12**. The operating device **25***a* is disposed in the operating cabin **14**. The operating device **25***a* receives operations from an operator for driving the work implement **13** and the travel device **12**, and outputs operation signals in accordance with the operations. The operating device **25***a* includes, for example, an operating lever, a pedal, and a switch and the like.

The input device **25***b* is a device for setting a below mentioned automatic control of the work vehicle **1**. The input device **25***b* receives an operation by an operator and outputs an operation signal corresponding to the operation. The operation signals of the input device **25***b* are output to the controller **26**. The input device **25***b* is, for example, a touch screen display. However, the input device **25***b* is not limited to a touch screen and may include hardware keys.

The controller **26** is programmed so as to control the work vehicle **1** based on obtained data. The controller **26** includes, for example, a processing device (processor) such as a CPU. The controller **26** obtains operation signals from the operating device **25***a* and the input device **25***b*. The controller **26** is not limited to one component and may be divided into a plurality of controllers. The controller **26** controls the travel device **12** or the power transmission device **24** thereby causing the work vehicle **1** to travel. The controller **26** controls the control valve **27** thereby causing the blade **18** to move up and down. The controller **26** controls the control valve **27** thereby causing the blade **18** to tilt.

The control valve **27** is a proportional control valve and is controlled with command signals from the controller **26**. The control valve **27** is disposed between the hydraulic pump **23** and hydraulic actuators such as the lift cylinder **19** and the tilt cylinder **21**. The control valve **27** controls the flow rate of the hydraulic fluid supplied from the hydraulic pump **23** to the lift cylinder **19** and the tilt cylinder **21**. The controller **26** generates a command signal for the control valve **27** so that the blade **18** moves. As a result, the lift cylinder **19** and the tilt cylinder **21** are controlled. The control valve **27** may also be a pressure proportional control valve. Alternatively, the control valve **27** may be an electromagnetic proportional control valve.

The control system **3** includes a lift sensor **29** and a tilt sensor **30**. The left sensor **29** detects the position of the work implement **13** in the vertical direction and outputs a work implement position signal which indicates the position of the work implement **13** in the vertical direction. The lift sensor

29 may be a displacement sensor that detects displacement of the work implement **13**. Specifically, the lift sensor **29** detects the stroke length (referred to below as "lift cylinder length Llift") of the lift cylinder **19**. FIG. **3** is a schematic side view of a configuration of the work vehicle **1**. As illustrated in FIG. **3**, the controller **26** calculates a lift angle θlift of the blade **18** based on the lift cylinder length Llift. The lift sensor **29** may also be a rotation sensor that directly detects the rotation angle of the work implement **13**.

The reference position of the work implement **13** is depicted as a chain double-dashed line in FIG. **3**. The reference position of the work implement **13** is the position of the blade **18** while the blade tip of the blade **18** is in contact with the ground surface on a horizontal ground surface. The lift angle θlift is the angle from the reference position of the work implement **13**.

The tilt sensor **30** detects the tilt angle of the work implement **13** and outputs a work implement position signal which indicates the tilt angle of the work implement **13**. The tilt sensor **30** may be a displacement sensor that detects displacement of the work implement **13**. Specifically, the tilt sensor **30** detects a stroke length of the tilt cylinder **21** (referred to below as "tilt cylinder length"). FIG. **4** is a schematic front view of a configuration of the work vehicle **1**. As illustrated in FIG. **4**, the controller **26** calculates a tilt angle θtilt of the blade **18** based on the tilt cylinder length. The tilt sensor **30** may also be a rotation sensor that directly detects the rotation angle of the work implement **13**.

As illustrated in FIG. **2**, the control system **3** includes a positional sensor **31**. The positional sensor **31** measures the position of the work vehicle **1**. The positional sensor **31** includes a global navigation satellite system (GNSS) receiver **32** and an IMU **33**. The GNSS receiver **32** is, for example, a receiving apparatus for a global positioning system (GPS). For example, an antenna of the GNSS receiver **32** is disposed on the operating cabin **14**. The GNSS receiver **32** receives a positioning signal from a satellite, computes the position of the antenna from the positioning signal, and generates vehicle body position data. The controller **26** obtains the vehicle body position data from the GNSS receiver **32**. The controller **26** derives the traveling direction and the vehicle speed of the work vehicle **1** from the vehicle body position data.

The vehicle body position data may not be data of the antenna position. The vehicle body position data may be data that indicates a position of an arbitrary location having a fixed positional relationship with an antenna inside the work vehicle **1** or in the surroundings of the work vehicle **1**.

The IMU **33** is an inertial measurement device. The IMU **33** obtains vehicle body inclination angle data. The vehicle body inclination angle data includes the angle (pitch angle) relative to horizontal in the vehicle front-back direction and the angle (roll angle) relative to horizontal in the vehicle lateral direction. The controller **26** obtains the vehicle body inclination angle data from the IMU **33**.

The controller **26** computes a blade tip position Pb from the lift cylinder length Llift, the vehicle body position data, and vehicle body inclination angle data. As illustrated in FIG. **3**, the controller **26** calculates global coordinates of the GNSS receiver **32** based on the vehicle body position data. The controller **26** calculates the lift angle θlift based on the lift cylinder length Llift. The controller **26** calculates local coordinates of the blade tip position Pb with respect to the GNSS receiver **32** based on the lift angle θlift and vehicle body dimension data.

The vehicle body dimension data is stored in the storage device **28** and indicates the position of the work implement **13** with respect to the GNSS receiver **32**. The controller **26** calculates the global coordinates of the blade tip position Pb based on the global coordinates of the GNSS receiver **32**, the local coordinates of the blade tip position Pb, and the vehicle body inclination angle data. The controller **26** obtains the global coordinates of the blade tip position Pb as blade tip position data.

In addition, the controller **26** calculates the tilt angle in the global coordinate system from the tilt angle θtilt in the aforementioned local coordinate system, the vehicle body position data, and the vehicle body inclination angle data. The global coordinate system may be a world-wide coordinate system or may be coordinate system based on the work site. The local coordinate system is a coordinate system based on the work vehicle **1**.

The storage device **28** includes, for example, a memory and an auxiliary storage device. The storage device **28** may be a RAM or a ROM, for example. The storage device **28** may be a semiconductor memory or a hard disk and the like. The storage device **28** is an example of a non-transitory computer-readable recording medium. The storage device **28** records computer commands for controlling the work vehicle **1** and that are executable by the processor.

The storage device **28** stores design topography data and work site topography data. The design topography data indicates the final design topography. The final design topography is a final target shape of the surface of the work site. The work site topography data is, for example, a civil engineering diagram map in a three-dimensional data format. The work site topography data indicates the topography of a wide area of the work site. The work site topography data is, for example, an actual topographical survey map in a three-dimensional data format. The work site topography data can be derived, for example, from an aerial laser survey.

The controller **26** obtains actual topography data. The actual topography data represents the actual topography of the work site. The actual topography of the work site is the topography of an area in the traveling direction of the work vehicle **1**. The actual topography data is obtained by computing by the controller **26** from the work site topography data and the position and the traveling direction of the work vehicle **1** obtained by the abovementioned positional sensor **31**. The actual topography data may be obtained by carrying out distance surveying on the actual topography with an on-board laser imaging detection and ranging device (LIDAR).

The controller **26** automatically controls the work implement **13** based on the actual topography data, the design topography data, and the blade tip position data. The automatic control of the work implement **13** may be a semi-automatic control that is performed in accompaniment to manual operations by the operator. Alternatively, the automatic control of the work implement **13** may be a fully automatic control that is performed without manual operations by an operator. The traveling of the work vehicle **1** may be controlled automatically by the controller **26**. For example, the travel control of the work vehicle **1** may be a fully automatic control that is performed without manual operations by an operator. Alternatively, the travel control may be a semi-automatic control that is performed in accompaniment with manual operations by an operator. Alternatively, the travel of the work vehicle **1** may be performed with manual operations by the operator.

Automatic control of the work vehicle **1** during excavation and executed by the controller **26** will be explained below. The controller **26** starts the automatic control when a predetermined starting condition is met. The predetermined starting condition may be, for example, the reception of an operation signal which indicates a lowering operation of the work implement **13** from the operating device **25***a*. Alternatively, the predetermined starting condition may be the reception of an operation signal indicating an automatic control starting command by the controller **26** from the input device **25***b*.

FIG. **5** is a flow chart of an automatic control process of the work vehicle **1**. As illustrated in FIG. **5**, the controller **26** obtains the current position data in step S**101**. The controller **26** obtains the current blade tip position Pb of the blade **18** as indicated above.

In step S**102**, the controller **31** obtains the design topography data. As illustrated in FIG. **6**, the design topography data includes a height Zdesign of a final design topography **60** at a plurality of reference points Pn (n=0, 1, 2, 3, . . . , A) in the traveling direction of the work vehicle **1**. The plurality of reference points Pn represent a plurality of spots at predetermined intervals in the traveling direction of the work vehicle **1**. The plurality of reference points Pn are on the travel path of the blade **18**. In FIG. **6**, while the final design topography **60** has a shape that is flat and parallel to the horizontal direction, the shape of the final design topography **60** may be different.

In step S**103**, the controller **26** obtains the actual topography data. The controller **26** obtains the actual topography data by computing from the work site topography data obtained from the storage device **28** and the vehicle body position data and the traveling direction data obtained by the positional sensor **31**.

The actual topography data is information indicative of the topography located in the traveling direction of the work vehicle **1**. FIG. **6** illustrates a cross-section of actual topography **50**. In FIG. **6**, the vertical axis represents the height of the topography and the horizontal axis represents the distance from the current position in the traveling direction of the work vehicle **1**.

Specifically, the actual topography data includes a height Zn of the actual topography **50** at each of the plurality of reference points Pn from the current position to a predetermined topography recognition distance dA in the traveling direction of the work vehicle **1**. In the present embodiment, the current position may be a position defined based on the current blade tip position Pb of the work vehicle **1**. However, the current position may also be defined based on the current position of another portion of the work vehicle **1**. The plurality of reference points are aligned with a predetermined interval, for example 1 m, between each point.

In step S**104**, the controller **26** determines target design topography data. The target design topography data represents a target design topography **70** indicated by the dashed line in FIG. **6**. The target design topography **70** represents a desired locus of the blade tip of the blade **18** during the work. The target design topography **70** is a target profile of the topography that is the work object and represents the desired shape as a result of the excavating work. As illustrated in FIG. **6**, the controller **26** determines at least a portion of the target design topography **70** located below the actual topography **50**.

The controller **26** determines the target design topography **70** so as not to go below the final design topography **60**. Therefore, the controller **26** determines the target design topography **70** located above the final design topography **60** and below the actual topography **50** during the excavating work.

In step S**105**, the controller **26** controls the work implement **13** in accordance with the target design topography **70**. The controller **26** generates command signals for the work implement **13** so as to move the blade tip position Pb of the blade **18** in accordance with the target design topography **70**. The generated command signal is inputted to the control valve **27**. Consequently, the blade tip position Pb of the blade **18** moves toward the target design topography **70**.

In step S**106**, the controller **26** updates the work site topography data. The controller **26** updates the work site topography data with the position data that represents the most recent locus of the blade tip position Pb. The update of the work site topography data may be performed at any time. Alternatively, the controller **26** may calculate the location of the bottom surface of the crawler belts **16** from the vehicle body position data and the vehicle body dimension data, and may update the work site topography data with the position data that represents the locus of the bottom surface of the crawler belts **16**. In this case, the updating of the work site topography data can be performed promptly.

Alternatively, the work site topography data may be generated from survey data measured by a survey device outside of the work vehicle **1**. For example, aerial laser surveying may be used as the external measurement device. Alternatively, the actual topography **50** may be imaged by a camera and the work site topography data may be generated from image data captured by the camera. For example, aerial photography surveying performed with an unmanned aerial vehicle (UAV) may be used. When using the external surveying device or a camera, the updating of the work site topography data may be performed at predetermined periods or at any time.

By repeating the above processes, the excavating is performed so that the actual topography **50** approaches the final design topography **60**.

The processing for determining the target design topography **70** is explained in detail below. FIG. **7** is a flow chart of a process for determining the target design topography **70**. As illustrated in FIG. **7**, in step S**201**, the controller **26** determines a starting point S**0**. As illustrated in FIG. **8**, the controller **26** determines, as the starting point S**0**, a position that is a predetermined distance L**1** in front of the blade tip position Pb at the point in time that the automatic control starts. The predetermined distance L**1** is saved in the storage device **28**. The input device **25***b* may be used to allow setting of the predetermined distance L**1**.

In step S**202**, the controller **26** determines a plurality of division points An (n=1, 2, . . .) based on the actual topography data. As illustrated in FIG. **8**, the controller **26** demarcates the actual topography **50** into a plurality of divisions according to the division points An. The division points An are spots positioned away from each other by a predetermined interval L**2** on the actual topography **50**. The predetermined interval L**2** is, for example, 3 m. However, the predetermined interval L**2** may be less than 3 m or greater than 3 m. The predetermined interval L**2** is saved in the storage device **28**. The input device **25***b* may be used to allow setting of the predetermined interval L**2**. The controller **26** determines, as the division points An, a plurality of spots at each predetermined interval L**2** in the traveling direction of the work vehicle **1** from the starting point S**0**.

In step S**203**, the controller **26** smooths the actual topography data. The controller **26** smooths the actual topography data by linear interpolation. Specifically, as illustrated in FIG. **9**, the controller **26** smooths the actual topography data by replacing the actual topography **50** with straight lines that link each of the division points An.

In step S**204**, the controller **26** determines a target depth L**3**. The controller **26** determines the target depth L**3** in accordance with a control mode set with the input device **25***b*. For example, the operator is able to select any of a first mode, a second mode, and a third mode with the input device **25***b*. The first mode is a control mode with the greatest load and the third mode is a control mode with the smallest load. The second mode is a control mode with a load between the first mode and the third mode.

The target depths L**3** corresponding to each mode are saved in the storage device **28**. The controller **26** selects, as the target depth L**3**, a first target depth of the first mode, a second target depth of the second mode, or a third target depth of the third mode. The first target depth is greater than the second target depth. The second target depth is greater than the third target depth. The input device **25***b* may be used to allow setting of the target depth L**3**.

In step S**205**, the controller **26** determines a plurality of reference points. As illustrated in FIG. **10**, the controller **26** determines, as respective reference points B**1** and B**2**, spots displaced downward by the target depth L**3** from the first preceding division point A**1** and from the second preceding division point A**2**.

In step S**206**, the controller **26** determines a plurality of reference topographies. As illustrated in FIG. **10**, the controller **26** determines a first reference topography C**1** and a second reference topography C**2**. The first reference topography C**1** is represented by a straight line that links the starting point S**0** and the first preceding reference point B**1**. The second reference topography C**2** is represented by a straight line that links the starting point S**0** and the second preceding reference point B**2**.

In step S**207**, the controller **26** determines the target design topography **70**. The controller **26** determines the target design topography **70** for each division demarcated by the plurality of division points An. As illustrated in FIG. **11**, the controller **26** determines a first target design topography **70_1** so as to pass through the first reference topography C**1** and the second reference topography C**2**. The first target design topography **70_1** is the target design topography **70** in the division between the starting point S**0** and the first preceding division point A**1**.

Specifically, the controller **26** calculates the average angle of the first reference topography C**1** and the second reference topography C**2**. The average angle is the average value between the angle of the first reference topography C**1** with respect to the horizontal direction and the angle of the second reference topography C**2** with respect to the horizontal direction The controller **26** determines, as the first target design topography **70_1**, a straight line that is inclined by the average angle with respect to the horizontal direction.

When the first target design topography **70_1** is determined as indicated above, in accordance with the abovementioned process of step S**105**, the controller **26** controls the work implement **13** in accordance with the first target design topography **70_1** as illustrated in FIG. **12**.

In step S**208**, the controller **26** determines the next starting point S**1**. The next starting point S**1** is the starting point of the next target design topography **70**, namely a second target design topography **70_2**. The second target design topography **70_2** is the target design topography **70** in the division between the next starting point S**1** and the first preceding division point A**2** from the starting point S**1**. As illustrated in FIG. **13**, the next starting point S**1** is the end position of the first target design topography **70_1** and is positioned directly below the division point A**1**.

Upon determining the next starting point S**1**, the controller **26** determines the second target design topography **70_2** by repeating the processes from step S**205** to step S**207**. The controller **26** determines the second target design topography **70_2** while working according to the first target design topography **70_1**.

Specifically, as illustrated in FIG. **13**, the controller **26** determines, as the next first reference topography C**1**, a straight line that links the next starting point S**1** and the first preceding reference point B**2** from the starting point S**1**. The controller **26** also determines, as the next second reference topography C**2**, a straight line that links the next starting point S**1** and the second preceding reference point B**3** from the starting point S**1**. The controller **26** determines the second target design topography **70_2** from the average angle of the first reference topography C**1** and the second reference topography C**2**.

When the work vehicle **1** reaches the next starting point S**1**, in accordance with the abovementioned process of step S**105**, the controller **26** controls the work implement **13** in accordance with the second target design topography **70_2**. The controller **26** then continues the excavation of the actual topography **50** by repeating the above processes.

When a predetermined completion condition is satisfied, the controller **26** finishes the abovementioned processes for determining the target design topography **70**. The predetermined completion condition is, for example, that the amount of material held by the work implement **13** has reached a predetermined upper limit. When the predetermined completion condition is satisfied, the controller **26** controls the work implement **13** so as to follow the actual topography **50**. Consequently, the excavated material can be smoothly transported.

The process when a manual operation of the work implement **13** is introduced by the operator during the abovementioned automatic control is explained next. FIG. **14** is a flow chart of a process when a manual operation is introduced. FIG. **15** is a front view of the work vehicle **1**, the final design topography **60**, the actual topography **50**, and the target design topography **70**. The size of the target design topography **70** in the vehicle width direction may be determined based on the dimensions of the work implement **13** in the vehicle width direction. Alternatively, the size of the target design topography **70** may be set with the input device **25***b*.

The controller **26** determines a target tilt angle in step S**301**. The controller **26** determines an initial value of the target tilt angle in accordance with the final design topography **60**. Specifically, as illustrated in FIG. **15**, the controller **26** determines the initial value of the target tilt angle so that the blade **18** is parallel to the final design topography **60**. When starting the automatic control, the controller **26** determines the aforementioned initial value as the target tilt angle. For example, as illustrated in FIG. **15**, when the final design topography **60** in the vehicle width direction is inclined at the angle θ1 with respect to the horizontal direction, the controller **26** determines the target tilt angle so that the tilt angle Atilt of the blade **18** with respect to the horizontal direction is θ1.

In step S**302**, the controller **26** determines the target design topography **70** based on the target tilt angle determined in step S**301**. When the target tilt angle is set to the initial value, the controller **26** determines the target design topography **70** so as to be parallel to the final design topography **60** in the vehicle width direction as illustrated in FIG. **15**. The controller **26** determines the target design topography **70** so as to match the final design topography **60** even if the actual topography **50** is inclined with respect to the final design topography **60**. As illustrated in FIG. **15**, when the final design topography **60** in the vehicle width direction is inclined with respect to the horizontal direction by the angle θ1, the controller **26** determines the target design topography **70** that is inclined by the angle θ1 with respect to the horizontal direction in the vehicle width direction. The shape of the target design topography **70** in the traveling direction of the work vehicle **1** is determined by the aforementioned processes from step S**201** to step S**208**.

When the target design topography **70** is determined as indicated above, in accordance with the abovementioned process of step S**105**, the controller **26** controls the blade **18** in accordance with the target design topography **70**. As illustrated in FIG. **15**, the controller **26** controls the blade **18** in accordance with the target design topography **70** while maintaining the tilt angle θtilt of the blade **18** at the target tilt angle. For example, as illustrated in FIG. **15**, the controller **26** controls the blade **18** in accordance with the first target design topography **70_1** illustrated in FIG. **12** while maintaining the tilt angle Atilt of the blade **18** at the target tilt angle.

In step S**303**, the controller **26** determines whether a manual operation has been performed. The controller **26** determines that a manual operation has been performed when an operation signal which indicates an operation for causing the work implement **13** to perform a tilting motion is received from the operating device **25***a*. The process advances to S**304** when the manual operation is performed.

In step S**304**, the controller **26** obtains the tilt angle θtilt changed due to the manual operation. The controller **26** may also obtain the changed tilt angle θtilt with a detection signal from the tilt sensor **30**. Alternatively, the controller **26** may also obtain the changed tilt angle θtilt with an operation signal from the operating device **25***a*.

In step S**305**, the controller **26** corrects the target tilt angle. The controller **26** corrects the target tilt angle in accordance with the changed tilt angle θtilt. The controller **26** corrects the target tilt angle so as to match the changed tilt angle θtilt.

In step S**306**, the controller **26** determines the target design topography **70** at the corrected target tilt angle. As illustrated in FIG. **16**, the controller **26** determines the target design topography **70** so as to be parallel to the blade **18** in the vehicle width direction.

In the examples in FIGS. **15** and **16**, the final design topography **60** in the vehicle width direction is inclined at the angle θ1 with respect to the horizontal direction. However, as illustrated in FIG. **17**, when the final design topography **60** in the vehicle width direction is horizontal, the controller **26** determines the target tilt angle so that the blade **18** is horizontal in step S**301**, and determines the target design topography **70** so as to be horizontal in the vehicle width direction in step S**302**. As illustrated in FIG. **18**, when the tilt angle Atilt is changed due to a manual operation, the controller **26** corrects the target tilt angle so as to match the changed tilt angle θtilt in step S**305**, and determines the target design topography **70** so as to be parallel to the blade **18** in the vehicle width direction in step S**306**.

In step S**307**, the controller **26** determines whether the target design topography **70** has exceeded the final design topography **60**. When the controller **26** determines that at least a portion of the target design topography **70** has exceeded the final design topography **60**, the process advances to step S**308**.

In step S**308**, the controller **26** corrects the target design topography **70** so that the target design topography **70** does not exceed the final design topography **60**. For example, as illustrated in FIG. **19**, when a lateral end **70***a* of the target design topography **70** exceeds the final design topography **60** in the downward direction, the controller **26** corrects the target tilt angle so that the lateral end **70***a* of the target design topography **70** is equal to or greater than the height of the final design topography **60** as illustrated in FIG. **20**. Alternatively, as illustrated in FIG. **21**, the controller **26** may correct the target tilt angle so that the target design topography **70** becomes parallel to the final design topography **60**.

As described above, when the tilt angle Rift of the blade **18** is changed due to a manual operation by the operator, the controller **26** determines the target design topography **70** so as to match the changed tilt angle θtilt. However, when at least a portion of the target design topography **70** exceeds the final design topography **60**, the target tilt angle is corrected so that the target design topography does not exceed the final design topography **60**. That is, when at least a portion of the target design topography **70** exceeds the final design topography **60**, the controller **26** prioritizes correcting the target tilt angle so that the target design topography does not exceed the final design topography **60** over correcting the target tilt angle in accordance with the operation of the operating device **25***a*.

In the control system **3** of the work vehicle **1** according to the present embodiment explained above, the controller **26** operates the work implement **13** in accordance with the target design topography **70**. As a result, when the final design topography **60** is still in a deep position, excavating by the work implement **13** is performed in accordance with the target design topography **70** that is positioned above the final design topography **60**. As a result, a situation in which the load on the work implement **13** becomes excessive is suppressed. In addition, the sudden raising or lowering of the work implement **13** is suppressed. Accordingly, the work vehicle **1** can be made to perform work efficiently and with a good finish quality.

When a manual operation of the work implement **13** is introduced by the operator during the automatic control, the controller **26** corrects the target tilt angle in response to the changed tilt angle θtilt and determines the target design topography **70** in accordance with the corrected target tilt angle. As a result, the intention of the operator can be reflected in the automatic control.

Although an embodiment of the present invention has been described so far, the present invention is not limited to the above embodiment and various modifications may be made within the scope of the invention.

The work vehicle **1** is not limited to a bulldozer, and may be another type of work vehicle such as a wheel loader, a motor grader, a hydraulic excavator, or the like.

The work vehicle **1** may be a vehicle that can be remotely operated. In this case, a portion of the control system **3** may be disposed outside of the work vehicle **1**. For example, the controller **26** may be disposed outside the work vehicle **1**. The controller may be disposed inside a control center spaced away from the work site. In this case, the work vehicle **1** may not be provided with the operating cabin **14**.

The work vehicle **1** may be driven by an electric motor. In this case, the power source may be disposed outside of the work vehicle **1**. The work vehicle **1** in which the power source is supplied from the outside may not be provided with the internal combustion engine or the engine compartment.

The controller **26** may have a plurality of controllers **26** separate from each other. For example, as illustrated in FIG. **22**, the controller **26** may include a remote controller **261** disposed outside of the work vehicle **1** and an on-board controller **262** mounted in the work vehicle **1**. The remote controller **261** and the on-board controller **262** may be able to communicate wirelessly. via communication devices **38** and **39**. A portion of the abovementioned functions of the controller **26** may be executed by the remote controller **261**, and the remaining functions may be executed by the on-board controller **262**. For example, the processes for determining the target design topography **70** may be performed by the remote controller **261**, and the processes for outputting the command signals to the work implement **13** may be performed by the on-board controller **262**.

The operating device **25***a* and the input device **25***b* may also be disposed outside of the work vehicle **1**. In this case, the operating cabin may be omitted from the work vehicle **1**. Alternatively, the operating device **25***a* and the input device **25***b* may be omitted from the work vehicle **1**.

The actual topography **50** may be obtained with another device and is not limited to being obtained with the above-mentioned positional sensor **31**. For example, as illustrated in FIG. **23**, the topography **50** may be obtained with an interface device **37** that receives data from an external device. The interface device **37** may wirelessly receive the actual topography data measured by an external measurement device **41**. Alternatively, the interface device **37** may be a recording medium reading device and may receive the actual topography data measured by the external measurement device **41** via a recording medium.

The method for setting the virtual design plane **70** is not limited to the method of the above embodiment and may be changed. For example, the target design topography **70** is determined based on two preceding reference points from the starting point in the above embodiment. However, the target design topography **70** may be determined based on three or more preceding reference points from the starting point.

The controller **26** determines the target design topography **70** based on the average angle between the first reference topography C**1** and the second reference topography C**2** in the above embodiment. However, the determination is not limited to the average angle and the controller **26** may determine the target design topography **70** by implementing a process such as weighting with the angle of the first reference topography C**1** and the angle of the second reference topography C**2**.

The controller **26** determines the second target design topography **70_2** during the work on the first target design topography **70_1** and before reaching the next starting position S**1** in the above embodiment. However, the controller **26** may determine the second target design topography **70_2** upon reaching the next starting point S**1**.

Alternatively, the controller **26** may determine the target design topography **70** with another method. The controller **26** may determine the target design topography **70** by displacing the actual topography **50** in the vertical direction. For example, as illustrated in FIG. **24**, the controller **26** may determine the target design topography **70** by displacing the actual topography **50** in the vertical direction by a target displacement dz. The target displacement dz may be determined in accordance with a parameter such as the machine capacity of the work vehicle **1** or the load received by the work vehicle **1**. The target displacement dz may also be set with the input device **25***b*.

In the above embodiment, the controller **26** determines the initial value of the target tilt angle so as to match the final design topography **60**. However, the controller **26** may determine the initial value of the target tilt angle irrespective of the final design topography **60**. For example, the controller **26** may use a previously set value as the initial value of the target tilt angle. Alternatively, the input device **25***b* may be used to allow optional setting of the initial value of the target tilt angle.

The controller **26** may control the work implement **13** so as to maintain the tilt angle θtilt of the blade **18** at the target tilt angle in the global coordinate system. That is, as illustrated in FIG. **25**A, the controller **26** may control the work implement **13** so as to maintain, at the target tilt angle, the tilt angle θtilt of the blade **18** with respect to the horizontal direction X_global. In this case, as illustrated in FIG. **25**B, even if the actual topography **50** is inclined and the attitude of the work vehicle **1** is tilted in the vehicle width direction, the attitude of the blade **18** in the global coordinate system can be constantly maintained.

However, the controller **26** may control the work implement **13** so as to maintain the tilt angle θtilt of the blade **18** at the target tilt angle in the local coordinate system of the work vehicle **1**. That is, as illustrated in FIG. **26**A, the controller **26** may control the work implement **13** so as to maintain, at the target tilt angle, the tilt angle θtilt of the blade **18** with respect to the vehicle width direction X_vehicle with respect to the work vehicle **1**. In this case, as illustrated in FIG. **26**B, even if the actual topography **50** is inclined and the attitude of the work vehicle **1** is tilted in the vehicle width direction, the attitude of the blade **18** with respect to the work vehicle **1** can be constantly maintained.

The controller **26** may switch between a first tilt angle control for maintaining the tilt angle θtilt of the blade **18** at the target tilt angle in the global coordinate system, and a second tilt angle control for maintaining the tilt angle θtilt of the blade **18** at the target tilt angle in the local coordinate system of the work vehicle **1**. For example, the controller **26** may switch between the first tilt angle control and the second tilt angle control in response to an operation of the input device **25***b*.

When the traveling direction of the work vehicle **1** is reversed, the controller **26** controls the work implement **13** so that the target tilt angle is reversed to the left and right while maintaining an absolute value of the target tilt angle with respect to the vehicle body **11**. For example, after the work vehicle **1** travels from the front to the back (outward path) with respect to the drawing surface in FIG. **27**A, the traveling direction is reversed, and the work vehicle **1** travels from the back side toward the front (return path) with respect to the drawing surface in FIG. **27**B.

In this case, as illustrated in FIG. **27**A, the controller **26** controls the work implement **13** so that the tilt angle θtilt is maintained at the target tilt angle with the left side pointing down with respect to the vehicle body **11** in the outward path. As illustrated in FIG. **27**B, the controller **26** controls the work implement **13** so that the tilt angle Atilt is maintained at the target tilt angle with the right side pointing down with respect to the vehicle body **11** in the return path. Consequently, the attitude of the blade **18** in the global coordinate system is maintained.

Even when the traveling direction of the work vehicle **1** is reversed, the controller **26** may control the work implement **13** so as to maintain the target tilt angle with respect to the vehicle body **11**. For example, after the work vehicle **1** travels from the front to the back (outward path) with respect to the drawing surface in FIG. **28**A, the traveling direction is reversed and the work vehicle **1** travels from the back side toward the front (return path) with respect to the drawing surface in FIG. **28**B.

In this case, as illustrated in FIG. **28**A, the controller **26** controls the work implement **13** so that the tilt angle θtilt is maintained at the target tilt angle with the left side pointing down with respect to the vehicle body **11** in the outward path. Then, as illustrated in FIG. **28**B, the controller **26** controls the work implement **13** so that the tilt angle θtilt is maintained at the target tilt angle with the left side pointing down with respect to the vehicle body **11** in the return path.

The controller **26** may switch between the first tilt angle control for reversing the target tilt angle to the left and right while maintaining an absolute value of the target tilt angle with respect to the vehicle body **11** when the traveling direction of the work vehicle **1** is reversed, and the second tilt angle control for maintaining the target tilt angle with respect to the vehicle body **11** even if the traveling direction of the work vehicle **1** is reversed. For example, the controller **26** may switch between the first tilt angle control and the second tilt angle control in response to an operation of the input device **25***b*.

In the present embodiment, when at least a portion of the target design topography **70** exceeds the final design topography **60**, the target tilt angle is corrected so that the target design topography does not exceed the final design topography **60**. However, the controller **26** may correct the target design topography **70** so as to not exceed the final design topography **60** using another method. For example, as illustrated in FIG. **29**, the position of the target design topography **70** may be corrected upward so that the target design topography **70** does not exceed the final design topography **60**.

According to the present invention, a work vehicle can be made to perform work efficiently and with a good finish quality with automatic control.

The invention claimed is:

1. A control system for a work vehicle including a work implement, the control system comprising:
- an operating device that outputs an operation signal indicative of manual operation by an operator; and
- a controller that communicates with the operating device and controls the work implement, the controller being configured to
  - determine an initial value of a target tilt angle,
  - determine a target design topography indicative of a target topography based on the initial value of the target tilt angle,
  - generate a command signal to operate the work implement automatically in accordance with the target design topography, and
  - when a tilt angle of the work implement is changed due to the manual operation of the operating device, obtain the tilt angle due to the manual operation as a changed tilt angle, correct the target tilt angle in accordance with the changed tilt angle to obtain a corrected target tilt angle, and determine the target design topography based on the corrected target tilt angle.

2. The control system for a work vehicle according to claim **1**, wherein
- the controller is configured to
  - generate the command signal to operate the work implement automatically in accordance with the target design topography at the target tilt angle.

3. The control system for a work vehicle according to claim **1**, wherein
- the controller is further configured to
  - obtain a final design topography indicative of a final target topography, and
  - determine the initial value of the target tilt angle in accordance with the final design topography.

4. The control system for a work vehicle according to claim **3**, wherein
- the controller is further configured to determine the initial value of the target tilt angle so that the work implement becomes parallel to the final design topography.

5. The control system for a work vehicle according to claim **2**, wherein
- the controller is further configured to control the work implement to maintain the tilt angle of the work implement in a global coordinate system at the target tilt angle.

6. The control system for a work vehicle according to claim **2**, wherein
- the controller is further configured to control the work implement to maintain the tilt angle of the work implement in a local coordinate system at the target tilt angle.

7. The control system for a work vehicle according to claim **2**, wherein
- the controller is further configured to maintain the target tilt angle even when a traveling direction of the work vehicle is reversed.

8. The control system for a work vehicle according to claim **2**, wherein
- the controller is further configured to reverse the target tilt angle between left and right while maintaining an absolute value of the target tilt angle when a traveling direction of the work vehicle is reversed.

9. The control system for a work vehicle according to claim **1**, wherein
- the operating device includes at least one of an operating lever, a pedal, or a switch.

10. The control system for a work vehicle according to claim **1**, wherein
- the controller is configured to correct the target tilt angle in accordance with the changed tilt angle such that the corrected target tilt angle is an angle at which the target design topography becomes parallel to the work implement in the vehicle width direction.

11. A method executed by a controller for controlling a work vehicle including a work implement, the method comprising:
- determining an initial value of a target tilt angle;
- determining a target design topography indicative of a target topography based on the initial value of the target tilt angle;
- generating a command signal to operate the work implement automatically in accordance with the target design topography;
- receiving an operation signal indicative of manual operation by an operator, from an operating device; and
- when a tilt angle of the work implement is changed due to the manual operation of the operating device, obtaining the tilt angle due to the manual operation as a changed tilt angle, correcting the target tilt angle in accordance with the changed tilt angle to obtain a corrected target tilt angle, and determining the target design topography based on the corrected target tilt angle.

12. The method according to claim **11**, wherein
- the generating the command signal to operate the work implement automatically includes generating the command signal to operate the work implement in accordance with the target design topography at the target tilt angle.

13. The method according to claim **11**, further comprising:
- obtaining a final design topography indicative of a final target topography, and

determining the initial value of the target tilt angle in accordance with the final design topography.

14. The method according to claim **13**, wherein

the determining the initial value of the target tilt angle includes determining the initial value of the target tilt angle so that the work implement becomes parallel to the final design topography.

15. The method according to claim **12**, further comprising:

maintaining the tilt angle of the work implement in a global coordinate system at the target tilt angle.

16. The method according to claim **12**, further comprising:

maintaining the tilt angle of the work implement in a local coordinate system at the target tilt angle.

17. The method according to claim **12**, further comprising:

maintaining the target tilt angle even when a traveling direction of the work vehicle is reversed.

18. The method according to claim **12**, further comprising:

reversing the target tilt angle between left and right while maintaining an absolute value of the target tilt angle when a traveling direction of the work vehicle is reversed.

19. The method according to claim **11**, wherein

the correcting the target tilt angle in accordance with the changed tilt angle being executed such that the corrected target tilt angle is an angle at which the target design topography becomes parallel to the work implement in the vehicle width direction.

20. A work vehicle comprising:

a work implement;

an operating device that outputs an operation signal indicative of manual operation by an operator; and

a controller that communicates with the operating device and controls the work implement, the controller being configured to

determine an initial value of a target tilt angle,

determine a target design topography indicative of a target topography based on the initial value of the target tilt angle,

generate a command signal to operate the work implement automatically in accordance with the target design topography, and

when a tilt angle of the work implement is changed due to the manual operation of the operating device, obtain the tilt angle due to the manual operation as a changed tilt angle, correct the target tilt angle in accordance with the changed tilt angle to obtain a corrected target tilt angle, and determine the target design topography based on the corrected target tilt angle.

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